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REFINER
AND NATURAL GASOLINE MANUFACTURER

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# The Look Box

INDUSTRIAL plants are usually built before the underlying theory of the process is fully understood. Scientific study comes later, followed by engineering application. The refining of petroleum is no exception. In fact, it reached almost its maximum growth unaided by research.

## Chemical Engineering

Today the story is entirely different. Progress in the science of oil refining is now so rapid that the most modern plant may become obsolete in about five years.

Petroleum refining is recognized as one of the most important branches of chemical engineering. It employs most of the basic unit operations and the modernization and improvements in the past fifteen years are due to the correct application of chemical engineering principles. The old rule-of-thumb days are gone forever. Laboratories are essential to the efficient operation of every plant.

Chemical engineering deals with processing operations, and certainly petroleum refining is a process industry. The application, however, of theoretical principles to the processing of petroleum is not simple. The complex nature of crude oil with its hundreds of components differing from each other by very small increments over a wide range almost defies ultimate analysis. In the ten years of intensive study and work by the American Petroleum Institute and the Bureau of Standards, forty-five compounds have been isolated from the gasoline fraction of the crude alone. This is indicative of the magnitude of the problem if knowledge of the ultimate constitution of crude oil is to be secured.

By reason of this complexity, refining equipment, particularly in distillation has been designed by compromise between theoretical and practical considerations. This compromise is usually effected by modification of equipment used in other industries. We usually think of the bubble tower as belonging to oil distillation, yet, its origin goes back to the alcohol industry in 1893.

It was over twenty years before fractionating columns were successfully applied to crude distillation and thirty years before general acceptance. But the reason is easily explained. First, the oil industry was not too receptive to ideas originating in other fields and second, the technical difficulties of design required a long period of development. That the first obstacle has been removed is readily apparent.

Refineries no longer attempt to design and construct their own major equipment. The great process engineering and construction firms have specialized in this field. Working against keen competition and faced with an increasing demand for new equipment they have been obliged to make every possible improvement in design.

It is as much the chemical engineer's job to operate plants as to design them. Of the two, operation is often the more difficult. The designer may

not anticipate every difficulty that will arise in operation, but the operator has to meet them with the plant the designer has given him. The knowledge picked up about the defects in design and operating problems is used to improve the next job.

It is no reflection upon engineering theory that so much reliance must be placed upon experimental data. The assumptions for mathematical design of distillation equipment are fairly accurate for two component systems, but are grossly in error when applied to petroleum distillation.

Distillation design furnishes the best example of the application of chemical engineering to oil refining because of its great importance. It is the governing factor in stabilization, cracking, redistillation and absorption operations. The success of the new solvent methods, both dewaxing and extraction, require complete and economical separation of solvents from oil, wax and extracts.

The greatest contribution of the chemical engineer to the petroleum industry is a new point of view. He accepts the fact that unit operations are not peculiar to any one product or to any one industry. Experience and theoretical considerations show that successful operations in one industry are helpful in designing processes and equipment for use in another. This is true even though the products may be entirely different.

The pipe still which is so necessary to the proper operation of the bubble tower is an adaptation of the water tube boiler. It required sixty years to perfect the water tube boiler because design and construction required so much more skill than for shell boilers. The engineering knowledge developed in that period helped to give us successful pipe stills in the short period since 1911. Pipe stills demonstrate correct application of the fundamentals of fluid and heat transfer.

Some processes, like acid treatment and cracking were inherited from the early coal oil industry, but it was not until sixty years later, with the advent of the Burton still, that the production of gasoline by cracking became a commercial success. Hydrogenation, which is again attracting serious attention, has been for many years used successfully in the hardening of vegetable and animal fats and in the liquefaction of coal. Polymerization is the method by which a number of familiar plastics are manufactured. Both hydrogenation and polymerization are essentially catalytic and success depends upon accurate control of conditions. These conditions have been determined by an intensive engineering study of the production of materials varying from hydrogen gas to heavy tar.

The use of such ideas need not indicate lack of originality on the part of refinery engineers, but they indicate the mutual dependence of all branches of industry. The petroleum industry has made its own impressive contributions to science and industry especially in the case of continuous processes with their all-important control instruments.

The refining of petroleum is becoming more and more chemical in its nature as the fundamental theory of each process becomes better understood. The industry now produces an ever widening variety of synthetic organic chemicals in important quantities.

In this brief resume of but a few of the applications of chemical engineering principles to petroleum refining no attempt has been made to include all of them. There is no doubt at all that the rapid and important developments of the last ten years are only a start. They are forerunners of an age when crude oil will be the raw material to furnish chemicals and products many of which are unknown today. Catalytic processes in particular will be responsible for the greatest change. The experimental data and fundamental science developed now will be invaluable in the petroleum industry tomorrow.

The foregoing analysis of chemical engineering as applied to petroleum refining is a generous abstract from a discussion presented by George F. Fitzgerald of the Socony-Vacuum Oil Company, Olean Refinery, before the recent annual meeting of the National Petroleum Association, Department of Manufacture and THE REFINER is indebted to its author for an excellent, thought provoking "guest editorial."

# Combination Oil and Gas Burners

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THIS present highly competitive, industrialized era demands closer attention to heat-conservation and fuel problems. The domestic consumer compares his fuel cost with that of his neighbor and the industrialist compares his fuel bills with those of his competitor. The manufacturer of fuel-burning equipment is ever striving to build more efficient fuel-burning devices. The boiler manufacturer is building smaller, more efficient boilers of greater capacity at less cost. Oil refineries are continually searching for better furnaces and fuel-burning equipment which will provide more even heat distribution and greater capacity for tube and cracking stills. Endless citations reflect the long forward strides engineers are making toward fuel conservation.

Before considering combination oil-and-gas burner design and operation it appears advisable to briefly discuss some fundamentals of combustion. For proper adjustment of the air-fuel ratio it is necessary to know the chemical reactions which take place when any fuel is burned. Combustion, for all practical purposes, is generally accepted as a chemical reaction of carbon, hydrogen, and sulphur, or their compounds, with oxygen. From the standpoint of heat production for industrial purposes combustion may be defined as the rapid combination of the combustible elements of any fuel with oxygen.

Fuel can be burned only as rapidly as the oxygen in the air can be intimately mixed with the fuel and no faster. Fuel-burning rates per cubic foot of furnace volume are, therefore, a function of the effective mixing of fuel and air by the burner. The fuel burner then becomes the more important factor, in so far as heat release per cubic foot of furnace volume is concerned. It is, of course, necessary for the heat liberated to be absorbed by some cooling medium after the burner has performed its duty of mixing the air and the fuel at any desired rate.

The three most essential factors in the successful burning of any fuel are time, temperature, and turbulence. If the time of burning is short, the turbulence and furnace temperature must be high. If the fuel-burning rate per cubic foot of furnace volume is low, the time factor is large and both temperature and turbulence may be low. If sufficient turbulence exists, furnace temperatures may be low and burning time may be short. The modern furnace temperature is usually low to keep furnace maintenance down, and the fuel-burning rate is high per cubic foot of furnace volume to obtain high capacity. Therefore, it is the duty of the burner to provide turbulence, or intimate mixing of the fuel and the air. Therefore, the burner which provides the greater amount of turbulence is more desirable.

Combination oil-and-gas burners should be able to burn either gas or fuel oil equally well, when burned separately or simultaneously. The engineer in charge of fuel conservation has only one opportunity to lower fuel consumption with existing equipment, and that is by lowering the heat losses up the stack by more accurate adjustment of the air-fuel ratio. The index of the air-fuel ratio is the percentage of carbon dioxide and oxygen in the flue gas, by Orsat analysis. In many instances, especially in oil refineries where natural gas is available, the natural gas is mixed with refinery gas in the refinery-gas system and this mixture of gas is burned in conjunction with fuel oil. Under these conditions it is difficult to calculate stack losses, or to calculate fuel savings made by proper adjustment of the air-fuel ratio. Also, it is advantageous to have a ready chart or graph, when individual fuels are burned, from which can be readily determined the percentage of stack loss when the flue-gas temperature and flue-gas analysis are known.

## COMBUSTION DATA

To eliminate, as far as possible, the tedious and laborious calculations of stack losses, Figure 1 and Table 1 are presented. Figure 1 shows graphically the total sinsible-heat content per pound mol for the constituent gases of the products of combustion from 0°F. to 5000°F. Table 1 shows the total sensible-heat content per pound mol and per pound for the constituent gases of the products of combustion from 0°F. to 5000°F. These data were calculated from equations derived from the United States Department of Commerce Bulletin No. 445[2]

The heat content per pound mol for the gases common in combustion work between any temperature range may be calculated from the following equations

$$H_{CO_2, SO_2} = (T_2 - T_1)\{7.7 + 1472 \times 10^{-6}(T_1 + T_2) - 8539 \times 10^{-11}[(T_1 + T_2)^2 - T_1T_2]\} \quad \ldots\ldots\ldots [1]$$

$$H_{O_2, N_2, CO, Air} = (T_2 - T_1)\{6.76 + 1683 \times 10^{-7}(T_1 + T_2) - 1337 \times 10^{-11}[(T_1 + T_2)^2 - T_1T_2]\} \quad \ldots\ldots\ldots [2]$$

$$H_{H_2O} = (T_2 - T_1)\{8.22 + 4165 \times 10^{-8}(T_1 + T_2) - 1379 \times 10^{-10}[(T_1 + T_2)^2 - T_1T_2]\} \quad \ldots\ldots\ldots [3]$$

where $T_1$ = lower temperature, deg Rankine, F abs; and $T_2$ = higher temperature, deg Rankine, F abs. The accuracy of Equations [1], [2], and [3] for temperature between 0 and 2500 F varies from 1.5 to 2.5 percent.

To determine the total heat content per pound of any gas it is only necessary to divide the total heat content per pound mol by the molecular weight of the gas.

Having determined the average flue-gas analysis and average flue-gas temperature, the stack loss may be calculated by either the pound or the pound-mol system. The pound-mol system is the more simple method and a detailed discussion of this method may be found elsewhere.[3] From the flue-gas analyses, the weights of the products of combustion are calculated and, by referring to Table 1, the heat content can be readily determined.

For illustrating the value of stack-loss charts for petroleum fuels, Figures 1, 2, 3, 4, 5, and 6 are presented. To determine the percent stack loss from Figures 2, 3, and 5, when the percent $CO_2$ and the stack temperature

[1] Combustion Engineer, Sinclair Refining Company. Mem. A.S.M.E. Contributed by the Fuels Division for presentation at the Spring Meeting of the American Society of Mechanical Engineers at Los Angeles, California, March 23-25, 1938.

NOTE: Statements and opinions advanced in papers are to be understood as individual expressions of their authors, and not those of the society nor this publication.

[2] "Specific Heat of Gases at High Temperatures," by E. D. Eastman, U. S. Bureau of Mines Technical Paper No. 445, Department of Commerce, Washington, D. C.

[3] "Molal Combustion and Graphical Representation of Stack Losses in Burning Petroleum Fuels," by O. F. Campbell, The Oil and Gas Journal, vol. 32, May 10, 1934, pp. 97-103.

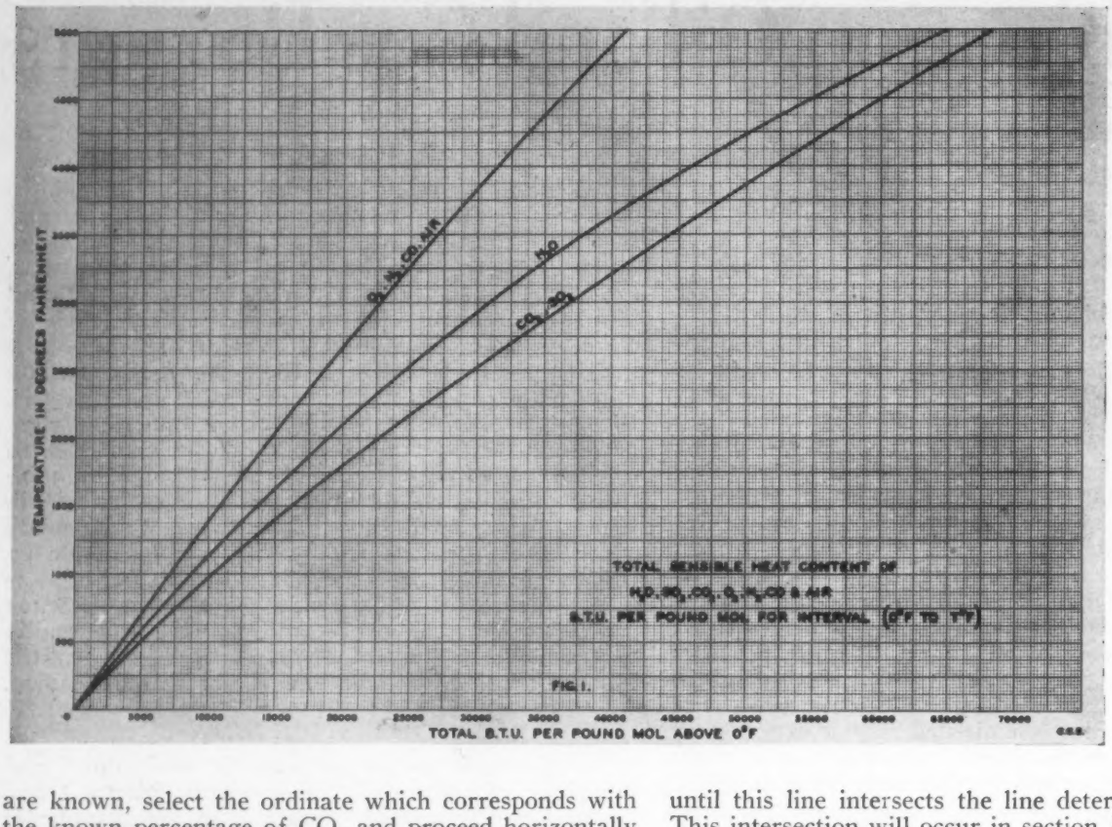


**FIGURE 1**

***Total Sensible Heat Per Pound Mol of $H_2O$, $SO_2$, $CO_2$, $O_2$, $N_2$, $CO$, and Air.***

are known, select the ordinate which corresponds with the known percentage of $CO_2$ and proceed horizontally to the right until the $CO_2$ curve is intersected, then proceed vertically up or down with an imaginary straight line until this line intersects the flue-gas-temperature line, then proceed horizontally to the scale which gives the stack loss in percent.

To determine the percent stack loss from either Figure 4 or Figure 6, when burning a mixture of known fuels and the percentages of $CO_2$ and $O_2$ and the stack temperature are known, the following nine steps are required:

*Step 1.* Select the point on the percent $CO_2$ scale in section *A* which corresponds with the known percent $CO_2$ and proceed vertically upward until the line representing the known percent $O_2$ is intersected.

*Step 2.* From this point of intersection of the percent $CO_2$ and percent $O_2$ in section *A* proceed horizontally to the left in an imaginary straight line until the line representing the known stack temperature is intersected in section *B*.

*Step 3.* Draw an imaginary straight line from the point determined in step 2 vertically downward until it intersects the line determined in step 6.

*Step 4.* Again select the point on the percent $CO_2$ scale in section *A* which corresponds with the known percent $CO_2$ and proceed vertically downward until the line representing the known stack temperature is intersected in section *D*.

*Step 5.* From the point determined in step 4 proceed horizontally left with an imaginary straight line until this imaginary line intersects the line representing Btu in $CO_2O_2N_2$.

*Step 6.* From this point draw an imaginary straight line parallel to the lines shown in section *C* until this imaginary line intersects the imaginary line drawn in step 3.

*Step 7.* From this point of intersection in section *C* draw an imaginary straight line horizontally to the right until this line intersects the line determined in step 9. This intersection will occur in section *E*.

*Step 8.* Select the point on the percent $CO_2$ scale in section *F* which corresponds with the known percent $CO_2$ and proceed horizontally to the left with an imaginary straight line until this line intersects the curve which represents the known percent $O_2$.

*Step 9.* From the point determined in step 8 proceed vertically downward with an imaginary straight line until the imaginary line determined in step 7 is intersected. The percent stack loss is determined by comparing the point of intersection determined in step 9 with the scale as shown in section *E*. The stack loss may be interpolated with a fair degree of accuracy to 0.5 percent.

The working basis for computing Figures 4 and 6 is 100 mols of dry flue gas. Section *A* is devoted to the water vapor produced when burning the hydrogen in the fuel and shows the amount of water vapor produced when enough fuel is burned to produce 100 mols of dry flue gas. It is also possible to estimate closely the percentage of each fuel burned when only two fuels are burned. The $O_2$ line is subdivided by the intersection of the $CO_2$ line, and the proportionate subdivision of this $O_2$ line gives the approximate proportionate amount of each of the two fuels burned. Section *B* is devoted to the total heat content of the water vapor produced per 100 mols of dry flue gas at the known temperature. Section *C* is devoted to the addition of the total heat in the dry flue gas and water vapor when enough fuel is burned to produce 100 mols of dry flue gas. Section *D* is devoted to the heat content per 100 mols of dry flue gas. Section *E* is devoted to the division of the stack loss and heat released per 100 mols of dry flue gas. Section *F* is devoted to the heat released per 100 mols of dry flue gas.

## CHOICE OF BURNER

Designs of combination oil-and-gas burners are many and varied, as shown in Figure 7. The engineer chooses the combination oil-and-gas burner which appears best

**Table 1—Sensible-Heat Content Per Pound Mol H and per pound h for $O_2$, $N_2$, $CO_2$, CO, $H_2O$, $SO_2$ and Air for a Temperature Range of 0 F to 5000 F**

| Temp. ° F. | | CO, $N_2$ | $O_2$ | Air | $H_2O$ | $CO_2$ | $SO_2$ |
|---|---|---|---|---|---|---|---|
| 0 | H | 000.0 | 000.0 | 000.0 | 000.0 | 000.0 | 000.0 |
| | h | 000.0 | 000.0 | 000.0 | 000.0 | 000.0 | 000.0 |
| 10 | H | 69.3 | 69.3 | 69.3 | 83.5 | 90.1 | 90.1 |
| | h | 2.5 | 2.2 | 2.4 | 4.6 | 2.0 | 1.4 |
| 20 | H | 138.5 | 138.5 | 138.5 | 167.0 | 180.5 | 180.5 |
| | h | 4.9 | 4.3 | 4.8 | 9.3 | 4.1 | 2.8 |
| 30 | H | 207.9 | 207.9 | 207.9 | 250.6 | 271.2 | 271.2 |
| | h | 7.4 | 8.5 | 7.2 | 13.9 | 6.2 | 4.2 |
| 40 | H | 277.2 | 277.2 | 277.2 | 330.4 | 362.1 | 362.1 |
| | h | 9.8 | 8.7 | 9.6 | 18.6 | 8.2 | 5.7 |
| 50 | H | 346.6 | 346.6 | 346.6 | 417.9 | 453.4 | 453.4 |
| | h | 12.4 | 10.8 | 12.0 | 23.2 | 10.3 | 7.1 |
| 60 | H | 416.1 | 416.1 | 416.1 | 501.6 | 544.9 | 544.9 |
| | h | 14.9 | 13.0 | 14.3 | 27.9 | 12.4 | 8.5 |
| 70 | H | 485.6 | 485.6 | 485.6 | 585.4 | 636.6 | 636.6 |
| | h | 17.3 | 15.2 | 16.7 | 32.5 | 14.5 | 9.9 |
| 80 | H | 555.1 | 555.1 | 555.1 | 669.2 | 728.6 | 728.6 |
| | h | 19.8 | 17.3 | 19.1 | 37.2 | 16.6 | 11.4 |
| 90 | H | 624.6 | 624.6 | 624.6 | 753.1 | 820.9 | 820.9 |
| | h | 22.3 | 19.5 | 21.5 | 41.8 | 18.7 | 12.8 |
| 100 | H | 694.2 | 694.2 | 694.2 | 837.0 | 913.4 | 913.4 |
| | h | 24.8 | 21.7 | 23.9 | 46.5 | 20.8 | 14.3 |
| 200 | H | 1392.2 | 1392.2 | 1392.2 | 1679.5 | 1853.5 | 1853.5 |
| | h | 49.7 | 43.5 | 48.0 | 93.3 | 42.1 | 29.0 |
| 212 | H | 1476.3 | 1476.3 | 1476.3 | 1781.1 | 1968.1 | 1968.1 |
| | h | 52.7 | 46.1 | 50.9 | 98.9 | 44.7 | 30.8 |
| 300 | H | 2094.1 | 2094.1 | 2094.1 | 2528.4 | 2819.7 | 2819.7 |
| | h | 74.8 | 65.4 | 72.2 | 140.5 | 64.1 | 44.1 |
| 400 | H | 2800.1 | 2800.1 | 2800.1 | 3384.3 | 3811.4 | 3811.4 |
| | h | 100.0 | 87.5 | 96.6 | 188.0 | 86.6 | 59.6 |
| 500 | H | 3509.9 | 3509.9 | 3509.9 | 4248.2 | 4828.0 | 4828.0 |
| | h | 125.4 | 109.7 | 121.0 | 236.0 | 109.7 | 75.4 |
| 600 | H | 4224.0 | 4224.0 | 4224.0 | 5120.8 | 5868.8 | 5868.8 |
| | h | 150.9 | 132.0 | 145.7 | 284.5 | 133.4 | 91.7 |
| 700 | H | 4942.4 | 4942.4 | 4942.4 | 6003.1 | 6934.7 | 6934.7 |
| | h | 176.5 | 154.4 | 170.4 | 333.5 | 157.6 | 108.4 |
| 800 | H | 5665.0 | 5665.0 | 5665.0 | 6895.8 | 8023.5 | 8023.5 |
| | h | 202.3 | 177.0 | 195.3 | 383.1 | 182.4 | 125.4 |
| 900 | H | 6392.0 | 6392.0 | 6392.0 | 7799.7 | 9135.2 | 9135.2 |
| | h | 228.3 | 199.8 | 220.4 | 433.3 | 207.6 | 142.7 |
| 1000 | H | 7123.5 | 7123.5 | 7123.5 | 8715.7 | 10269.2 | 10269.2 |
| | h | 254.4 | 222.6 | 245.6 | 484.2 | 233.4 | 160.5 |
| 1100 | H | 7859.5 | 7859.5 | 7859.5 | 9644.7 | 11425.4 | 11425.4 |
| | h | 280.7 | 245.6 | 271.0 | 535.8 | 259.7 | 178.5 |
| 1200 | H | 8600.0 | 8600.0 | 8600.0 | 10587.4 | 12603.0 | 12603.0 |
| | h | 307.1 | 268.8 | 296.6 | 588.2 | 286.4 | 196.9 |
| 1300 | H | 9345.3 | 9345.3 | 9345.3 | 11544.6 | 13801.6 | 13801.6 |
| | h | 333.8 | 292.0 | 322.3 | 641.4 | 313.7 | 215.7 |
| 1400 | H | 10095.4 | 10095.4 | 10095.4 | 12517.3 | 15020.6 | 15020.6 |
| | h | 360.5 | 315.5 | 348.1 | 695.4 | 341.4 | 234.7 |
| 1500 | H | 10850.3 | 10850.3 | 10850.3 | 13506.8 | 16259.5 | 16259 5 |
| | h | 387.5 | 339.1 | 374.1 | 750.4 | 369.5 | 254.1 |
| 1600 | H | 11610.2 | 11610.2 | 11610.2 | 14512.0 | 17517.8 | 17517.8 |
| | h | 414.7 | 362.8 | 400.4 | 806.2 | 398.1 | 273.7 |
| 1700 | H | 12375.1 | 12375.1 | 12375.1 | 15535.9 | 18795.0 | 18795.0 |
| | h | 442.0 | 386.7 | 426.7 | 863.1 | 427.2 | 293.7 |
| 1800 | H | 13145.2 | 13145.2 | 13145.2 | 16578.4 | 20089.1 | 20089.1 |
| | h | 469.5 | 410.8 | 453.3 | 921.0 | 456.6 | 313.9 |
| 1900 | H | 13920.4 | 13920.4 | 13920.4 | 17640.3 | 21396.6 | 21396.6 |
| | h | 497.2 | 435.0 | 480.0 | 980.0 | 486.3 | 334.3 |
| 2000 | H | 14700.9 | 14700.9 | 14700.9 | 18722.7 | 22734.9 | 22734.9 |
| | h | 525.0 | 459.4 | 506.9 | 1040.2 | 516.7 | 355.2 |
| 2100 | H | 15486.6 | 15486.6 | 15486.6 | 19826.3 | 24082.5 | 24082.5 |
| | h | 553.1 | 484.0 | 534.0 | 1101.5 | 547.3 | 376.3 |
| 2200 | H | 16277.8 | 16277.8 | 16277.8 | 20951.9 | 25446.5 | 25446.5 |
| | h | 581.3 | 508.7 | 561.3 | 1164.0 | 578.3 | 397.6 |
| 2300 | H | 17074.5 | 17074.5 | 17074.5 | 22100.3 | 26826.3 | 26826.3 |
| | h | 609.8 | 533.6 | 588.8 | 1227.8 | 609.7 | 419.2 |
| 2400 | H | 17876.7 | 17876.7 | 17876.7 | 23272.4 | 28221.2 | 28221.2 |
| | h | 638.5 | 558.6 | 616.4 | 1292.9 | 641.4 | 441.0 |
| 2500 | H | 18685.0 | 18685.0 | 18685.0 | 24469.0 | 29631.3 | 29631.3 |
| | h | 667.3 | 583.9 | 644.3 | 1359.4 | 673.4 | 463.0 |
| 2600 | H | 19498.4 | 19498.4 | 19498.4 | 25690.9 | 31055.4 | 31055.4 |
| | h | 696.4 | 609.3 | 672.4 | 1427.3 | 705.8 | 485.2 |
| 2700 | H | 20317.9 | 20317.9 | 20317.9 | 26939.0 | 32493.4 | 32493.4 |
| | h | 725.6 | 634.9 | 700.6 | 1496.6 | 738.5 | 507.7 |
| 2800 | H | 21143.3 | 21143.3 | 21143.3 | 28214.1 | 33944.5 | 33944.5 |
| | h | 755.1 | 660.7 | 729.1 | 1567.5 | 771.5 | 530.4 |
| 2900 | H | 21974.8 | 21974.8 | 21974.8 | 29516.9 | 35408.5 | 35408.5 |
| | h | 784.8 | 686.7 | 757.8 | 1639.8 | 804.7 | 553.3 |
| 3000 | H | 22812.3 | 22812.3 | 22812.3 | 30848.4 | 36884.6 | 36884.6 |
| | h | 814.7 | 712.9 | 786.6 | 1713.8 | 838.3 | 576.3 |
| 3100 | H | 23655.9 | 23655.9 | 23655.9 | 32209.4 | 38372.5 | 38372.5 |
| | h | 844.9 | 739.2 | 815.7 | 1789.4 | 872.1 | 599.6 |
| 3200 | H | 24505.7 | 24505.7 | 24505.7 | 33600.6 | 39871.6 | 39871.6 |
| | h | 875.2 | 765.8 | 845.0 | 1866.7 | 906.2 | 623.0 |
| 3300 | H | 25361.8 | 25361.8 | 25361.8 | 35023.0 | 41381.3 | 41381.3 |
| | h | 922.1 | 792.6 | 874.5 | 1945.7 | 940.5 | 646.6 |
| 3400 | H | 26224.3 | 26224.3 | 26224.3 | 36477.3 | 42901.3 | 42901.3 |
| | h | 936.6 | 819.5 | 904.3 | 2026.5 | 975.0 | 670.3 |
| 3500 | H | 27093.3 | 27093.3 | 27093.3 | 37964.7 | 44430.9 | 44430.9 |
| | h | 967.6 | 846.7 | 934.3 | 2109.2 | 1009.8 | 694.2 |
| 3600 | H | 27968.8 | 27968.8 | 27968.8 | 39485.0 | 45969.7 | 45969.7 |
| | h | 998.9 | 874.0 | 964.4 | 2193.6 | 1044.8 | 718.3 |
| 3700 | H | 28850.0 | 28850.0 | 28850.0 | 41040.1 | 47517.1 | 47517.1 |
| | h | 1030.4 | 901.6 | 994.8 | 2280.0 | 1079.9 | 742.5 |
| 3800 | H | 29739.9 | 29739.9 | 29739.9 | 42630.5 | 49072.7 | 49072.7 |
| | h | 1062.1 | 929.4 | 1025.5 | 2368.4 | 1115.3 | 766.8 |
| 3900 | H | 30635.5 | 30635.5 | 30635.5 | 44256.9 | 50635.7 | 50635.7 |
| | h | 1094.1 | 957.4 | 1056.4 | 2458.7 | 1150.8 | 791.2 |
| 4000 | H | 31538.0 | 31538.0 | 31538.0 | 45920.3 | 52206.9 | 52206.9 |
| | h | 1126.4 | 985.6 | 1087.5 | 2551.1 | 1186.5 | 815.7 |
| 4100 | H | 32447.5 | 32447.5 | 32447.5 | 47621.3 | 53782.9 | 53782.9 |
| | h | 1158.8 | 1014.0 | 1118.9 | 2645.6 | 1222.3 | 840.4 |
| 4200 | H | 33364.0 | 33364.0 | 33364.0 | 49361.0 | 55365.9 | 55365.9 |
| | h | 1191.6 | 1042.6 | 1150.5 | 2742.3 | 1258.3 | 865.1 |
| 4300 | H | 34287.5 | 34287.5 | 34287.5 | 51140.0 | 56954.4 | 56954.4 |
| | h | 1224.6 | 1071.5 | 1182.3 | 2841.1 | 1294.4 | 889.9 |
| 4400 | H | 35218.3 | 35218.3 | 35218.3 | 52959.2 | 58548.0 | 58548.0 |
| | h | 1257.8 | 1100.6 | 1214.4 | 2942.2 | 1330.6 | 914.8 |
| 4500 | H | 36156.4 | 36156.4 | 36156.4 | 54819.5 | 60146.1 | 60146.1 |
| | h | 1291.3 | 1129.9 | 1246.8 | 3045.5 | 1367.0 | 939.8 |
| 4600 | H | 37101.7 | 37101.7 | 37101.7 | 56721.7 | 61748.3 | 61748.3 |
| | h | 1325.1 | 1159.4 | 1279.4 | 3151.2 | 1403.4 | 964.8 |
| 4700 | H | 38054.5 | 38054.5 | 38054.5 | 58666.5 | 63353.9 | 63353.9 |
| | h | 1359.1 | 1189.2 | 1312.2 | 3259.3 | 1439.9 | 989.9 |
| 4800 | H | 39014.9 | 39014.9 | 39014.9 | 60654.9 | 64962.6 | 64962.6 |
| | h | 1393.4 | 1219.2 | 1345.3 | 3369.7 | 1476.4 | 1015.0 |
| 4900 | H | 39982.8 | 39982.8 | 39982.8 | 62687.7 | 66569.2 | 66569.2 |
| | h | 1428.0 | 1249.5 | 1378.7 | 3482.7 | 1512.9 | 1040.1 |
| 5000 | H | 40958.3 | 40958.3 | 40958.3 | 64765.6 | 68187.0 | 68187.0 |
| | h | 1462.8 | 1280.0 | 1412.4 | 3598.1 | 1549.7 | 1065.4 |

**Note**—Data in this table were compiled from reference given in footnote 2 of this paper.

to him for any particular installation and, after operating his choice, he will generally wish he had chosen another combination. The purchaser of combination oil-and-gas burners may purchase any type, or combination of types, desired to suit any particular furnace, or character of fuel oil or gas to be burned. Where funds available are low and fuel prices are low, the purchaser may find it to his advantage to buy a rather inefficient cheap burner.

The choice of a combination oil-and-gas burner presents many problems. The first consideration is that the burner must operate over a long period of time without cleaning or repair. The burner must also be designed for quick cleaning during operation with minimum outage. For wide-swinging firing rates, the burner must be flexible enough in capacity to meet the maximum and minimum loads and meet each load equally well. For high-temperature preheated air, the burner must be built of material which will withstand the preheated-air temperature. Air and fuel velocities should be of such magnitude that ignition will be satisfactory.

## REQUIREMENTS

The fundamental requirements of the oil-burning features of the combination oil-and-gas burner for efficient operation are, first, the burner must thoroughly atomize the oil and, second, the atomized oil must be forced into the air stream to give a thorough, intimate mixture of oil with the proper amount of air. These results can best be obtained by preheating the fuel oil. The fuel oil may be atomized mechanically, or by either high- or low-pressure air, or by steam. These methods of atomization arranged in the order of low total cost are (1) mechanical, (2) steam, (3) low air pressure, (4) high air pressure; the total cost includes fixed charges and operating costs. The fundamental requirements of the gas-burning feature, for efficient gas burning in combination oil-and-gas burners, are, first, that the gas must be intimately mixed with the air for combustion, in order that no unburned or incompletely burned gas will escape from the furnace; second, that the burner will not plug up readily; and, third, that the burner should be designed for quick cleaning, with minimum outage and, if possible, for cleaning while in operation.

## FLAME PROPAGATION AND IGNITION

Combustion literature reveals that flame propagation for gaseous fuels is low. It is, of course, necessary, when designing a burner, to have the air-gas velocity

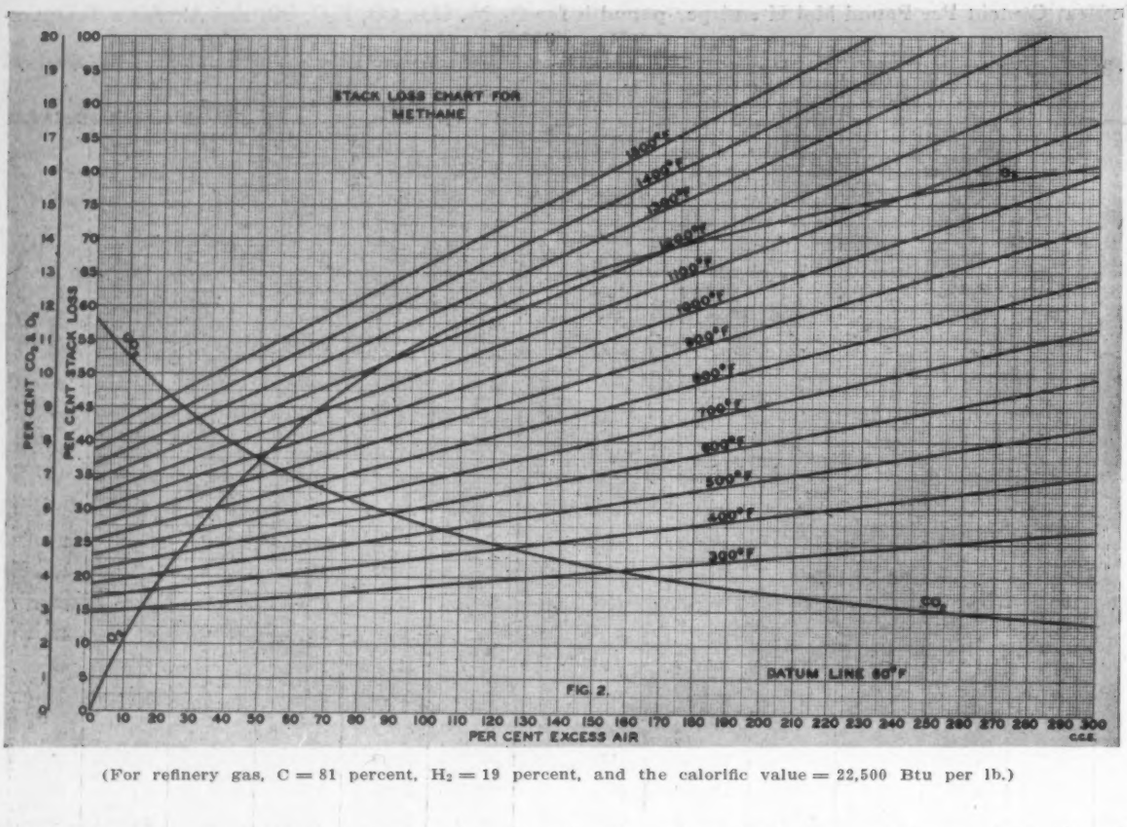


**FIGURE 2**
***Stack-Loss Chart for Methane***

(For refinery gas, C = 81 percent, $H_2$ = 19 percent, and the calorific value = 22,500 Btu per lb.)

greater than the speed of flame propagation, in order to prevent flarebacks in the burner.[4] The speed of uniform movement or flame propagation for methane, using cold air in a 1-inch diameter tube, is 2.2 fps. For a 12-inch tube under the same conditions, the flame-propagation speed is approximately 5.5 fps. With these low flame-propagation speeds, little or no trouble is encountered when designing a burner, since the air-fuel mixture through the burner is usually several times the flame-propagation speed.

One of the more important problems in burner design is whether or not the burner will stay lighted, regardless of the air velocity through the burner itself. The air and fuel velocities leaving the burner must be of such magnitude that ignition will be certain. The author has had the opportunity to test ignition,

[4] "Fuels and Their Combustion," by R. T. Haslam and R. P. Russell, McGraw-Hill Book Company, New York, N. Y., 1926, pp. 266-271 and pp. 479-481.

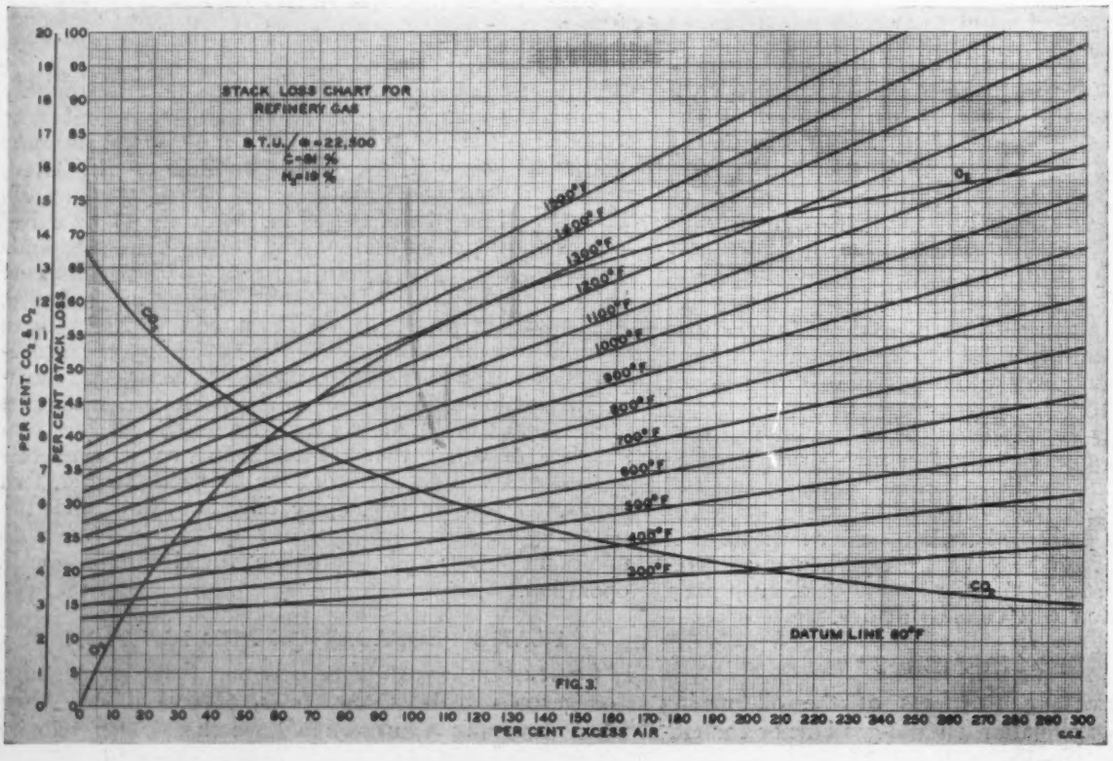


**FIGURE 3**
***Stack-Loss Chart for Refinery Gas***

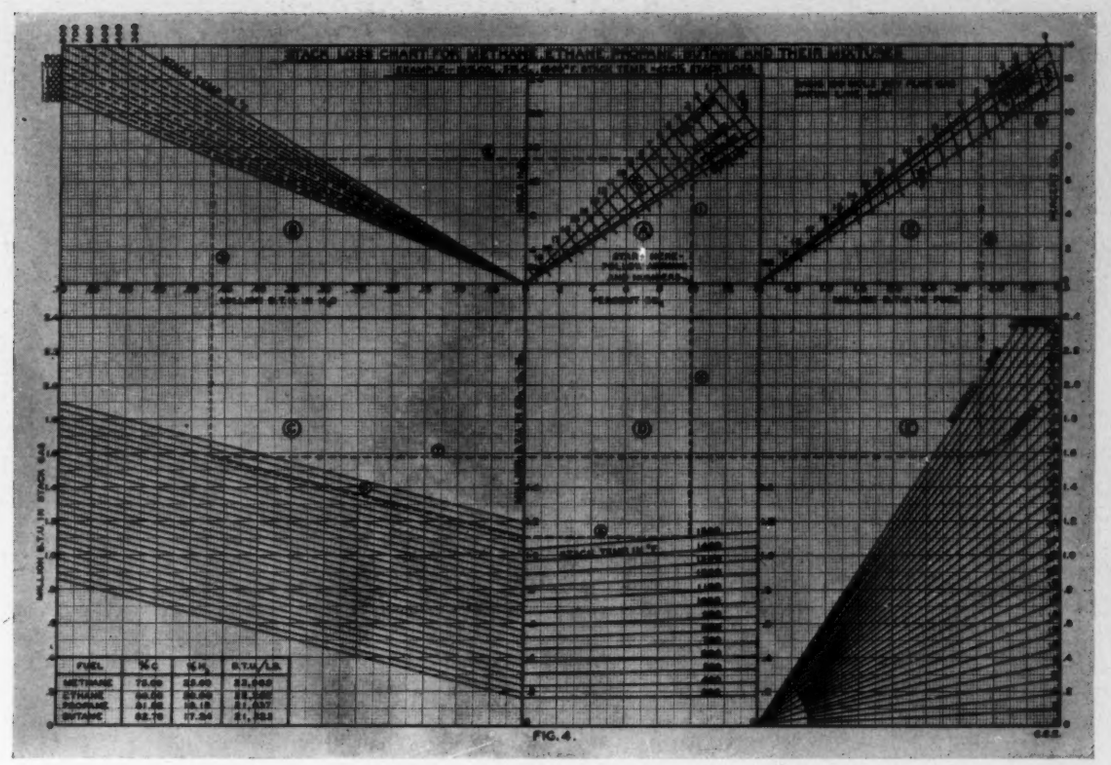

FIG. 4.

**FIGURE 4**

***Stack - Loss Chart for Methane, Ethane, Propane, Butane, and their Mixtures.***

using a short 6-inch tube with cold air, streamlined flow, and ignition could be maintained with an air-gas velocity of approximately 70 fps when burning methane. It was further found, when burning methane with an air temperature of 750°F. and streamlined flow through a short 6-inch tube, that ignition could be maintained with an air-gas velocity of approximately 160 fps. Under the same conditions, using turbulent flow instead of streamlined flow, ignition could be maintained with the air-fuel velocity through the tube greater than 400 fps. The turbulent flow was of such a nature as to cause the air-and-gas mixture to expand quickly after emerging from the end of the tube, which slowed down the velocity and allowed ignition to take place. In most cases, high velocities of the air-fuel mixture are neither necessary nor economical at the present time, except in special cases, but what may now be the exception may later be the rule. It appears that ignition is a function of velocities, turbulence and temperature

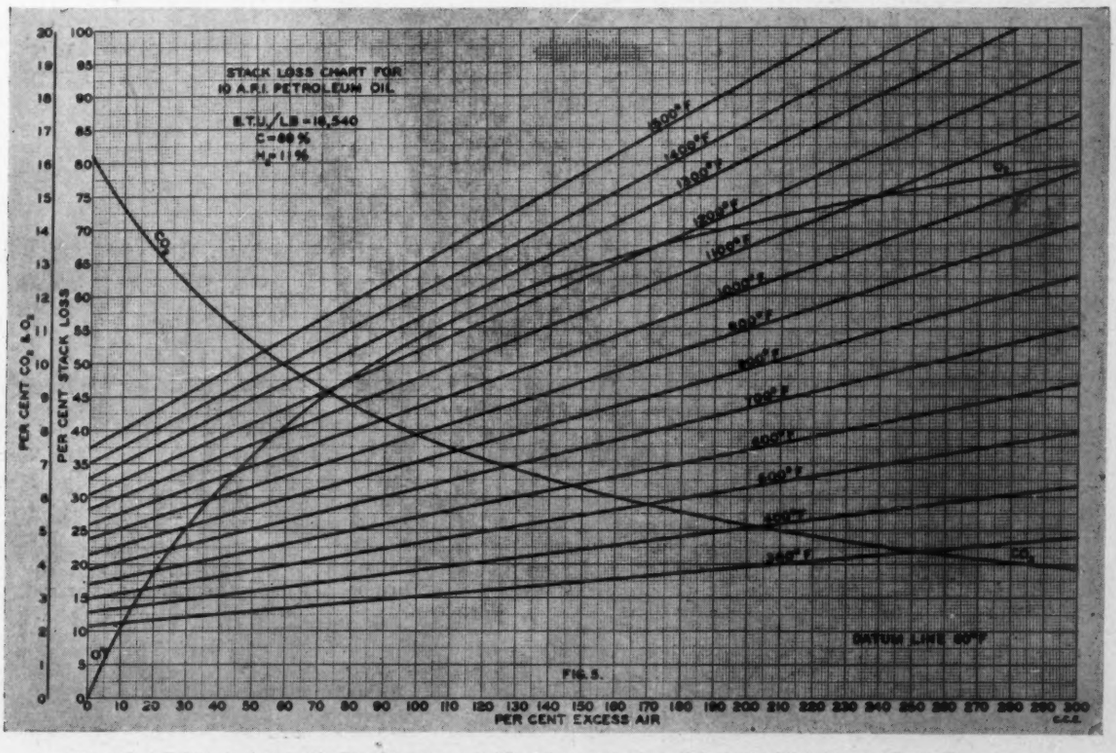


FIG. 5.

**FIGURE 5**

***Stack-Loss Chart for 10 A.P.I. Petroleum Oil.***

(For 10 A.P.I: petroleum oil, C = 89 per cent, $H_2$ = 11 per cent, and the calorific value = 18,540 Btu per lb.)

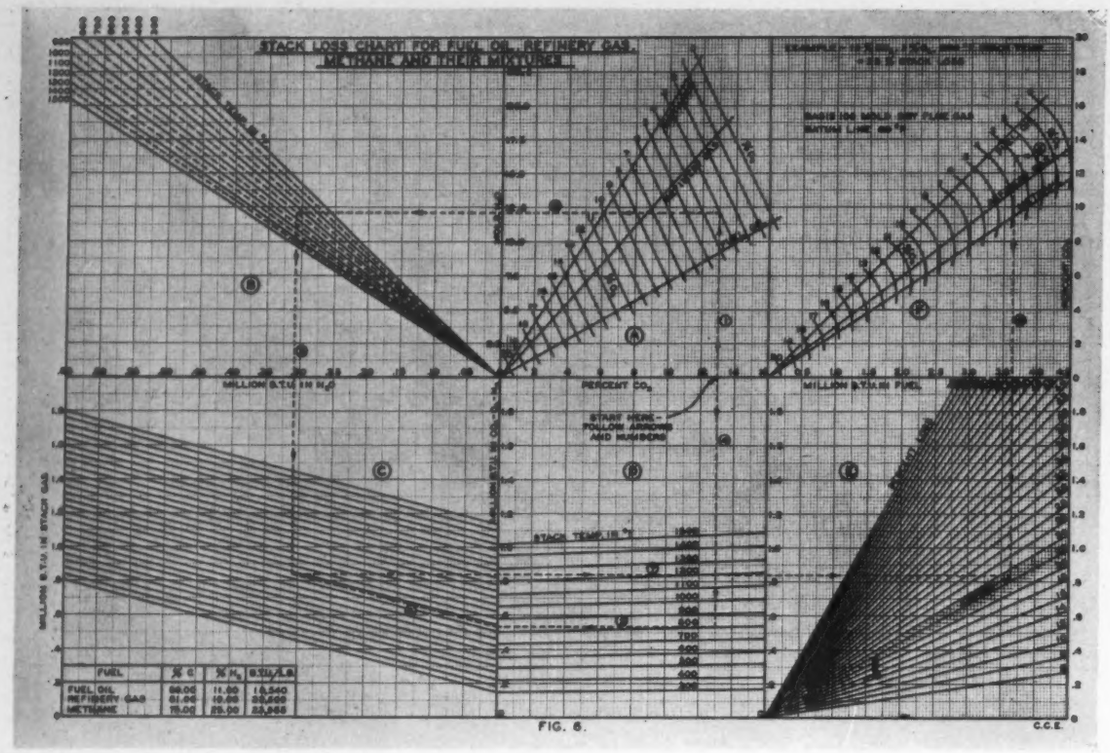


**FIGURE 6**

***Stack - Loss Chart for Fuel Oil, Refinery Gas, Methane, and their Mixtures.***

*after* the air-fuel mixture has passed through the burner and not a function of the air and gas velocities through the burner.

## BURNER TROUBLES NOT USUALLY RECOGNIZED

Many a solid or an air-cooled refractory wall has failed due to uneven heat distribution and the refractory has been blamed. Boiler waterwall blocks have disintegrated prematurely because of uneven heat distribution in the furnace, due to either burner or wind-box design. Improper mixing of air and fuel has resulted in long flames, delayed combustion, high localized hot spots in the furnace, and over-all inefficient operation. A poor air-fuel mixture has caused furnace pulsations, which eventually caused failure of furnace walls, trouble with forced- and induced-draft fans, uneven steam output from boilers and, in one known case, the furnace vibration was so great as to cause the breaking of the glass in the windows of the building. The blame for these troubles is usually placed upon everything but the burner, and the burner is usually the cause. The author has investigated many trouble jobs where the fuel oil was supposed to be the cause of the trouble, and in every case the trouble was corrected by changing either the burner or the furnace and continuing to use the same fuel oil. These experiences have prompted the author to work with the burner manufacturer to make a better new burner and to revamp old burners to give satisfactory results. Some

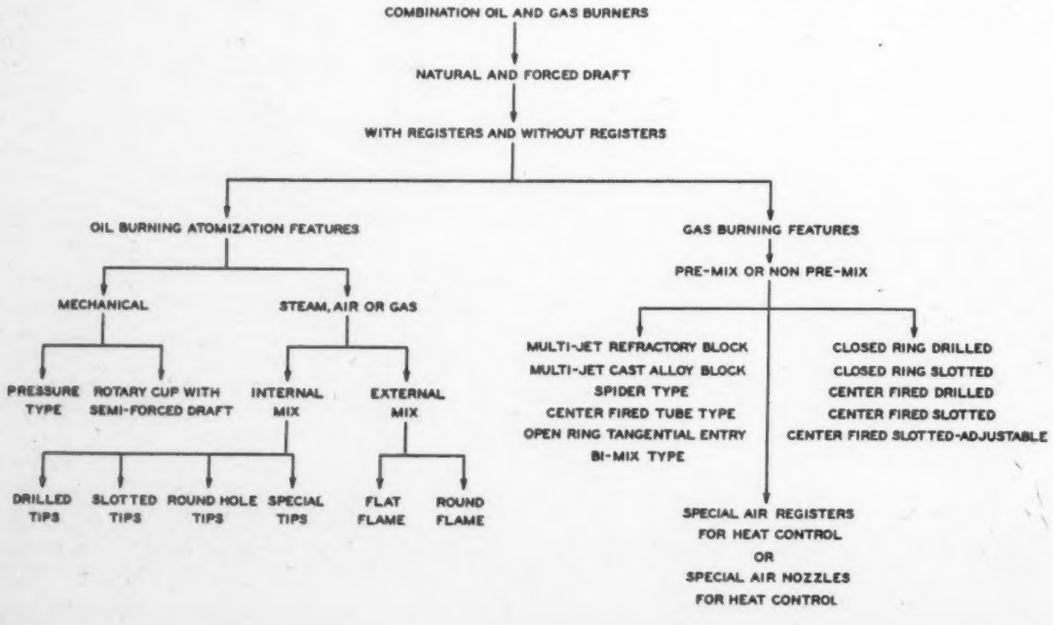


**FIGURE 7**

***General Classification of Combination Oil and Gas Burners.***

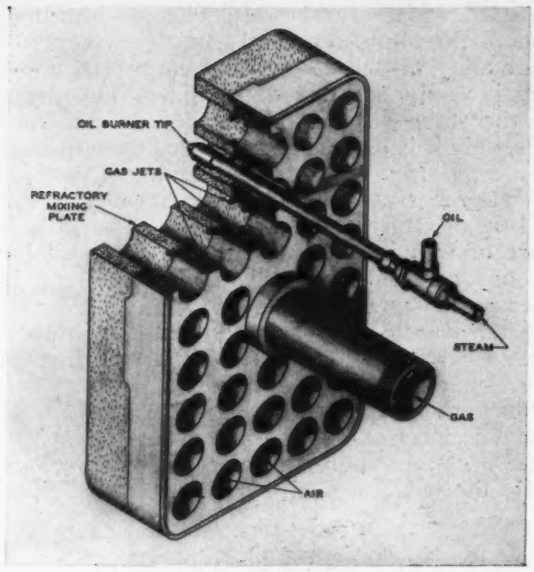


**FIGURE 8**

***Combination Oil-and-Gas Burner which has a Multi-Jet Non-premix Gas Burner and Steam-Atomizing Oil Burner with Drilled Tip—Used for Forced or Natural Draft and Hot or Cold Air.***

(Courtesy of Lee B. Mettler Company, Los Angeles, Calif.)

types of burners do not provide the proper turbulence or intimate air-fuel mixture and must use a better grade of fuel oil for satisfactory results. It has been the author's experience that any grade of fuel oil that can be delivered to the burner will burn satisfactorily, provided the burner design is correct.

## DESCRIPTION AND DISCUSSION OF SOME REPRESENTATIVE TYPES OF INDUSTRIAL COMBINATION OIL-AND-GAS BURNERS

There are many types of combination oil-and-gas burners available and a few representative types are herewith presented for description and discussion. It would be impossible to present in a single paper all types of industrial combination oil-and-gas burners on the market; therefore, the author is presenting some of those with which he is more familiar. An impartial discussion, including both favorable and unfavorable characteristics of each burner described, is presented. There may be more favorable or more unfavorable characteristics than presented for each type and opinions may differ, but it is hoped that this paper will present construction and operating characteristics, whereby the purchaser may make a more intelligent selection of a combination burner for any particular installation.

Figure 8 shows a combination oil-and-gas burner, which may be used with natural or forced draft and hot or cold air. The gas-burning feature consists of a cast-iron or alloy cellular block protected by a cellular refractory tile. The cast block and the refractory tile have a number of round holes, or cells, through which the air for combustion passes. The gas is introduced at the entrance of the protecting tile through two or more drilled nozzles or jets. The burner usually operates on only a few ounces of gas pressure and requires low draft when burning gas, due to the aspirating effect of the gas jets. A cast-alloy block may be used to replace the refractory protecting block. The burner may be equipped with premixers, but to do so requires enlargement of the air-gas jets to compensate for the increased volume of air-gas mixture passing through the jets. Other burners of this type use a single gas jet placed in the center of each air-gas port and may use air-gas cells other than round. There are many modifications of this type of burner, some of which incorporate the venturi principle of air injection. The oil-burning feature of this burner may be either a mechanical-pressure type of a steam-atomizing oil burner with round tip. The steam-atomizing burner may have either a drilled or a slotted flat tip. The author prefers a flat-flame oil-burner tip for this type of burner.

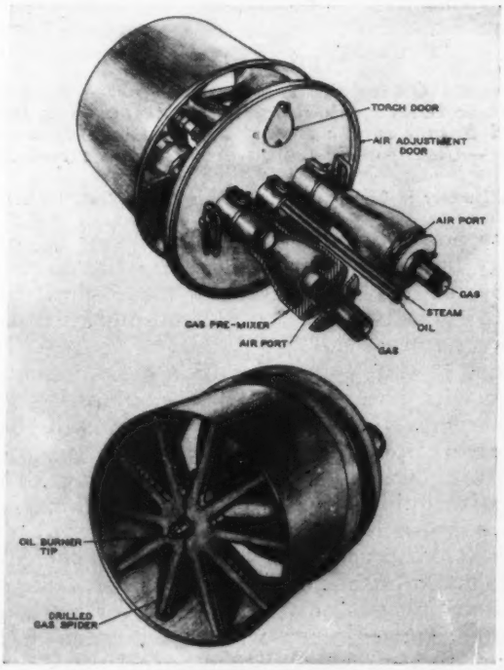


**FIGURE 9**

***Combination Oil-and-Gas Burner which has a Two-Section Premix Drilled Gas Spider and a Steam-Atomizing Internal-Mix Oil Burner with a Round Drilled Tip—Used for Natural Draft and Cold Air.***

(Courtesy of John Zink Company, Tulsa, Okla.)

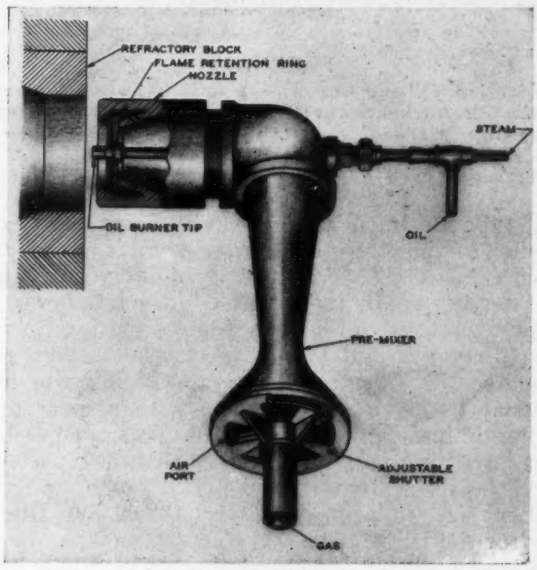


**FIGURE 10**

***Combination Oil-and-Gas Burner which has an Open-Port Premix Gas Burner with an Adjustable Air Shutter and a Steam-Atomizing Internal-Mix Oil Burner with a Round-Hole Tip—Used for Natural Draft and Cold Air.***

(Courtesy of Maxon Premix Burner Company, Muncie, Ind.)

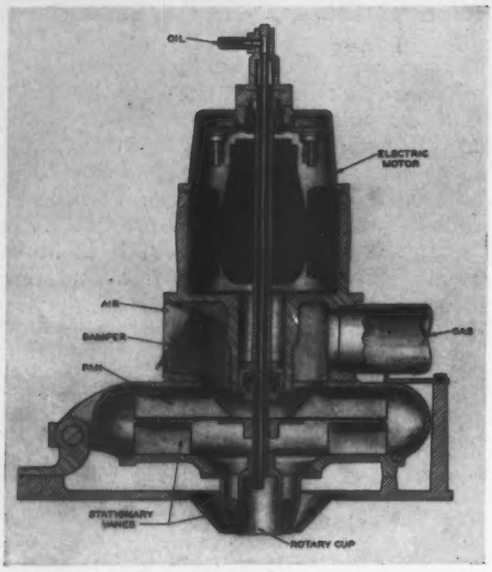


**FIGURE 11**

***Combination Oil-and-Gas Burner which has a Mechanical Premix Gas Burner with an Adjustable Air Damper and a Rotary-Cup Mechanical-Atomizing Oil Burner—Used for Semiforced Draft and Cold Air.***

(Courtesy of Williams Brothers and Miller, East Chicago, Ind.)

This type of burner can operate with low excess air, due to the large number of small air-gas ports. When clean, it provides a very good air-gas mixture. Due to the small, inaccessible gas chambers, it is difficult to clean and has a tendency to plug up when using dirty gas and more especially so when using preheated air. The refractory protecting tile has a tendency to get out of position with respect to the casting, unless carefully installed. This type of burner has a wide application and varies in capacity for the various sizes from 500,000 Btu per hour for the smaller size to approximately 13,000,000 Btu per hour for the larger size.

Figure 9 shows a combination oil-and-gas burner

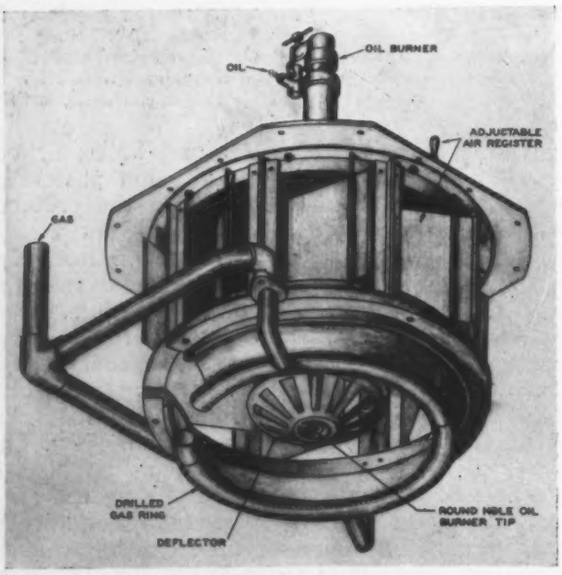


**FIGURE 12**

***Combination Oil-and-Gas Burner which has a Two-Section Nonpremix Drilled Gas Ring, a Pressure-Type Mechanical-Atomising Oil Burner, and an Adjustable Air Register—Used for Forced Draft and Hot or Cold Air.***

(Courtesy of The Babcock & Wilcox Company, New York, N. Y.)

to be used with natural draft. The gas-burning feature is of the bimix type and has a two-section cast-iron or alloy drilled spider, and each section of the spider is equipped with a premixer. The premixer is of the same general design as used in domestic stoves, only it is built on a larger scale and uses high-pressure gas to provide the premixing. Either a mechanical-pressure type or a steam-atomizing, drilled, round-tip oil burner may be used for the oil-burning feature of this burner. A flat slotted-tip oil burner may also be used. The advantages of this type of burner are: Its simplicity, ease of ignition, its ability to better handle gas of high calorific value, wide range of flexibility, does not plug up readily, and is easily cleaned. Dust-laden air has a tendency to plug up the premixer and during extremely cold weather, when it is used outside, it has a tendency to freeze up the premixer. For natural draft, the burners are usually limited in capacity to approximately 25,000,-

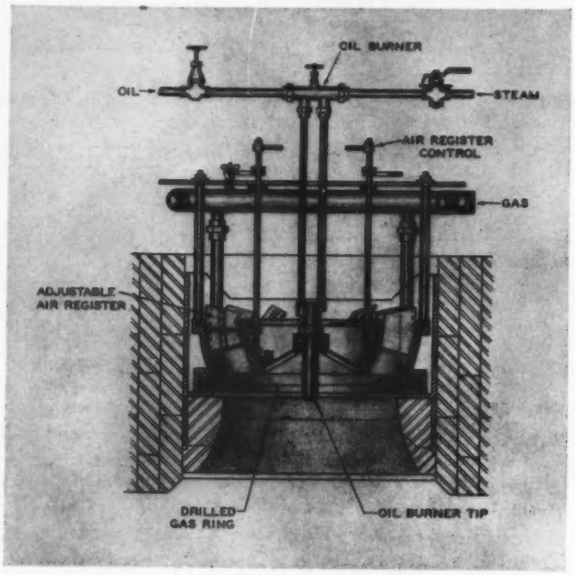


**FIGURE 13**

***Combination Oil-and-Gas Burner which has a Four-Section Nonpremix Drilled Gas Ring, a Steam-Atomizing Internal-Mix Oil Burner with a Drilled Tip, and an Adjustable Air Register—Used for Forced or Natural Draft and Hot or Cold Air.***

(Courtesy of The Engineer Company, New York, N. Y.)

000 Btu per hour, and usually a number of smaller-capacity burners are used instead of the larger ones. This burner may be used with forced-draft hot air with more satisfactory results at higher capacities than for natural draft.

Figure 10 shows a combination oil-and-gas burner for use with natural draft. The gas-burning feature of this combustion oil-and-gas burner is of the venturi premix type and usually requires gas pressure from 0.5 to 30 pounds per square inch gage. The gas nozzle is equipped with a flame-retention ring for positive ignition without the use of baffles or ignition tunnels. This burner utilizes the energy of the gas pressure to accomplish the mixing of the air and gas and, when burning gas only, no blowers or air compressors are required, even with the furnace operating under a slight pressure. When burning gas, with the furnace operating under a slight pressure, the capacity of the burner is reduced approximately two thirds. The oil-burning feature of this burner consists of a steam-atomizing internal-mixing oil burner with a round-hole tip, although narrow-angle flat slotted

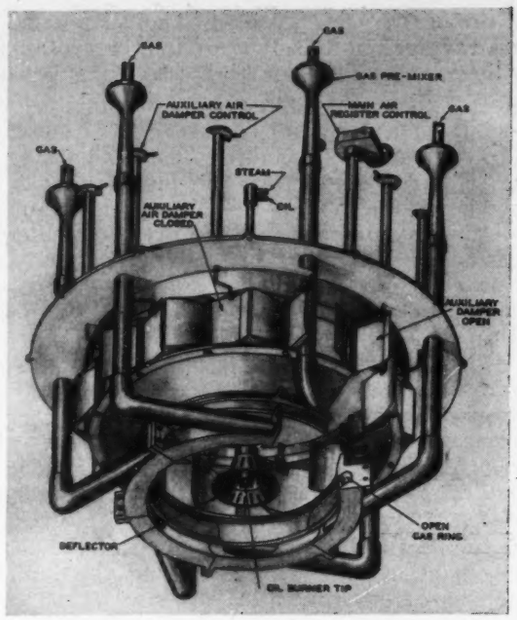


**FIGURE 14**

***Combination Oil-and-Gas Burner which has a Six-Section Premix Tangential-Entry Open Gas Ring, a Steam-Atomizing Internal-Mix Oil Burner with a Round Flat Drilled Tip, and an Adjustable Air Register with Auxiliary Dampers for Air Control—Used for Forced Draft and Hot or Cold Air.***

(Courtesy of the Peabody Engineering Corporation, New York, N. Y.)

tips may be used. When burning fuel oil, auxiliary air is required and is usually obtained by opening auxiliary-air doors under the burner nozzle. This burner can also be readily converted to use forced-draft hot air. The maximum size of this burner available is limited to approximately 14,000,000 Btu per hour, but the author presumes that larger sizes could be built if desired. The disadvantages of this type of combination oil-and-gas burner are: Its large size with respect to capacity, necessity of using high gas pressure, possibility of the aspirator plugging up

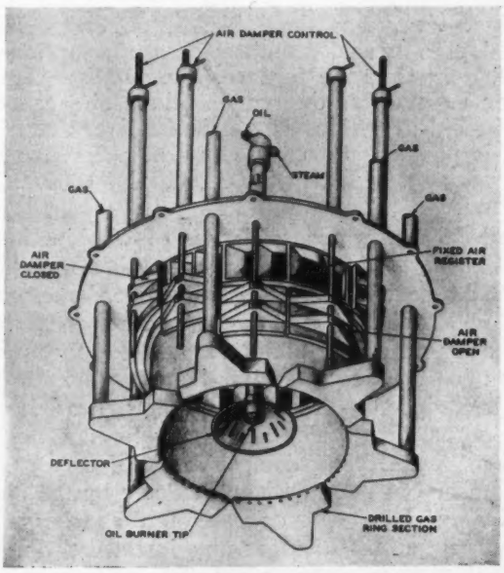


**FIGURE 15**

***Combination Oil-and-Gas Burner which has a Six-Section Nonpremix Drilled Gas Ring, a Steam-Atomizing Internal-Mix Oil Burner with a Drilled Cone Tip, and a Fixed Air Register with Adjustable Dampers for Air Control—Used for Forced Draft and Hot or Cold Air.***

(Courtesy of Coen Company, Inc., San Francisco, Calif.)

with dust-laden air and freezing up at extremely low temperatures when used outside. The advantages of this type of burner are: Flexibility, intimate mixing of air and gas over wide ranges without blowers or compressors, and ability to retain ignition, handle gas of high calorific value, and produce high rates of heat release per cubic foot of furnace volume.

Figure 11 shows a combination oil-and-gas burner using cold air, semiforced draft, a mechanical premix gas burner and a rotary-cup mechanical-atomiz-

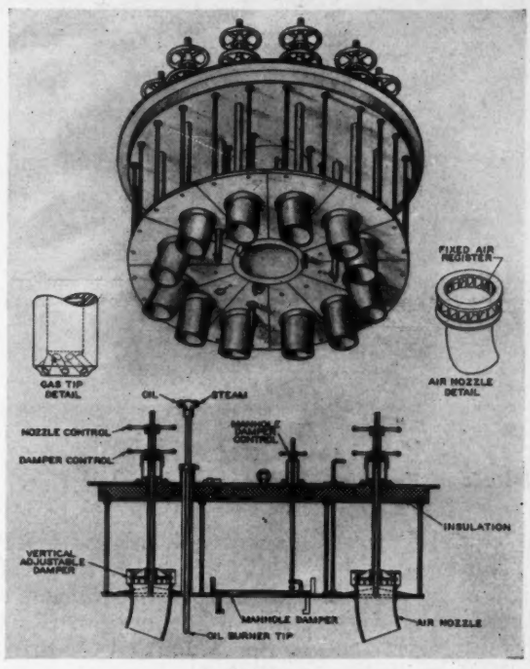


**FIGURE 16**

***Special-Alloy Combination Oil-and-Gas Burner which has 12 Dampered Fixed-Register Air Nozzles Capable of 360-Deg Rotation, Special Drilled Nonpremix Gas-Burner Tips, Three Steam-Atomizing Internal-Mix Oil Burners with Drilled Cone Tips, and an Adjustable Center Manhole for Secondary-Air Control—Used for Forced Draft and Hot Air.***

(Courtesy of Coen Company, Inc., San Francisco, Calif.)

ing oil burner. The oil is delivered to the rotary cup through the hollow motor shaft and atomized by the rotary cup and low-pressure air delivered around the cup by means of a fan having a speed the same as the cup. Secondary air is admitted into the furnace through a brick checkerwork floor. When burning gas, the gas is admitted into the suction of the fan along with the air used for aiding in the atomization of the oil. The gas and air to the burner may be controlled automatically, if desired, but is usually controlled manually. The advantages of this type of combination burner are: Its ability to handle any grade of fuel oil that can be delivered to the burner, or gas of any calorific value at any pressure that may be available. The main disadvantage is the difficulty of adjustment of the air-gas ratio leaving the burner to prevent flarebacks in the burner. This type of burner is best applied to installations where on-and-off control is satisfactory. The air-gas ratio is set for safe operation and the burner operates at full load or at no load. The maximum capacity of this type of burner built to date is approximately 13,000,000 Btu per hour for gas and 16,000,000 Btu per hour for fuel oil. There appears to be no reason why this burner cannot be built with greater capacity if desired.

Figure 12 illustrates a combination oil-and-gas

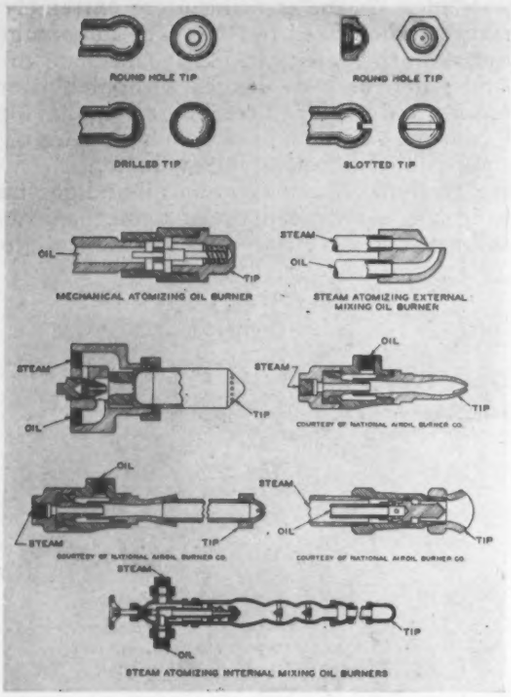


**FIGURE 17**
***Details of Various Oil Burners and Burner Tips.***

burner equipped to use hot or cold air with forced draft. The gas-burning features are: A two-section cast-iron or alloy drilled gas ring, not equipped with premixers. For presentation of the design, the gas-ring protecting refractory tile is omitted for this and the following illustrations where protecting tile is required. The oil-burning feature of this burner consists of a mechanical-pressure type oil burner. The forced-air supply for the burner is delivered through an adjustable air register to provide turbulence. There are many variations in design of this type of burner, such as: (1) Different design of gas ring, (2) different design and size of deflectors, (3) different number and pitch and curvature of air register vanes, and (4) different design of fuel-oil nozzles. This type of burner may also be used with a steam-atomizing oil burner. The disadvantages of the design presented are: (1) Plugging up of gas-ring ports when using dirty gas, (2) difficulty in cleaning and replacing the gas ring, (3) lack of flexibility when burning fuel oil, due to the mechanical fuel-oil atomization, and (4) inability to control heat distribution in the furnace. The advantages of the design presented are: (1) Forced draft, with its attendant high capacity, and (2) an adjustable air register to provide a variation in turbulence for variations in fuel-oil or gas-burning rates. The usual designed capacities vary from 10,000,000 to 50,000,000 Btu per hour, but can be designed for greater capacity.

Figure 13 illustrates a combination oil-and-gas burner equipped to use forced or natural draft and hot or cold air. The gas-burning feature of this design consists of a four-section nonpremix drilled gas ring. The shape of the gas ring is designed to conform to the venturi burner throat. The oil-burning feature of this burner consists of a steam-atomizing internal-mix oil burner with drilled oil-burner tip. The air register is of special design and provides turbulent air flow through a venturi burner throat. An adjustable vane control is incorporated to allow air to pass immediately around the oil-burner tip, when using fuel oil. The advantages and the disadvantages of this type of burner are approximately the same as given for Figure 12.

Figure 14 illustrates a special type of combination oil-and-gas burner designed for use with 1000°F. preheated air and heat-distribution control. The gas-burning feature consists of a six-section, half-open alloy gas ring. Each section of the gas ring is equipped with a premixer and the air-gas mixture from the premixer enters the gas ring tangentially, providing a rotary motion in the open gas ring. The oil-burning feature consists of a steam-atomizing internal-mixing oil burner with a flat drilled tip. Other designs of drilled tips are also satisfactory. The air register consists of adjustable curved blades to provide turbulence, and is equipped with special auxiliary dampers for heat-distribution control in the furnace. The advantages of this burner are: (1) It has premixers to handle gas of high calorific value, (2) it has an open-type gas ring, which eliminates plugging of gas ring, (3) the premixer can be removed and the turbine can be run through one section of the gas ring during operation without interrupting the remaining five sections of gas ring, (4) it has an adjustable air register for controlling turbulence for both high and low firing rates, (5) flexibility, and (6) it has auxiliary air dampers for heat-distribution control in the furnace. The disadvantages of this type of burner are: (1) High-pressure gas is required for premixing, (2) premixers plug up with dust-laden air and freeze up when extremely cold air enters aspirators, (3) mechanical difficulties are encountered when adjusting the air dampers and (4) high wind-box pressures are required to obtain capacity and heat-distribution control. The maximum capacity of this special design of burner is between 55,000,000 and 60,000,000 Btu per hour, but smaller-capacity burners may be designed with satisfactory operating results.

Figure 15 shows another type of combination oil-and-gas burner designed for use with 1000°F. preheated air and heat-distribution control. The gas-burning feature consists of a six-section drilled nonpremix gas ring. The fuel-oil-burning feature consists of a steam-atomizing internal-mixing drilled cone-tip oil burner. The air register has fixed blades, or vanes, and is equipped with special auxiliary dampers for heat-distribution control in the furnace. The auxiliary dampers cover or uncover, as desired, the fixed air register to obtain heat distribution. The main disadvantage of this burner is plugging up of the gas ring. Its maximum capacity is approximately 55,000,000 to 60,000,000 Btu per hour.

Figure 16 shows a special type of combination oil-and-gas burner designed for use with 1100°F. preheated air, with a capacity of 100,000,000 Btu per hour, and for firing downward. The gas-burning features consist of 12 curved alloy air tubes, or nozzles, inserted through and resting upon a 12-section alloy bottom plate. Each air nozzle is equipped with a fixed air register, as shown in the air-nozzle detail. The air supply to each nozzle is controlled by a circular damper inside of each register. This damper can be moved up or down by the damper control wheel. The gas is delivered to the center of each air nozzle by means of a gas pipe inserted through the individual damper-control pipes. The ends of the gas-supply pipes are welded and drilled, as shown in the gas-tip detail. The air nozzle can be rotated by means of a nozzle-control wheel through an angle of 360 degrees to obtain heat distribution to any part of the furnace. The

[*Continued on page 329*]

# Economic Aspects of Polymerization

DR. M. B. COOKE*

THE refiner has been called upon more and more frequently during the past few years to evaluate the merits of new processes all of which (according to the sponsors) were developed for the specific purpose of aiding the refiner to make a profit out of current losses. In order to refine his daily quota of oil, the refiner has had more to do than to listen to process salesmen. Some of us have been guilty of overselling an idea, perhaps unwittingly, but nevertheless, the refiner has been called upon to make selections from the varied processes offered him, among them polymerization. Many installations have been made which were truly "trial balloons" and we wish to pay our respects to those refiners who have taken a chance with the equipment and with the concerns offering new processes. Some installations have been highly profitable while others have paid less returns than the tax collectors have received in their annual harvest.

In looking around for some reason for this difference in success with the newer processes, such as the polymerization of refinery by-product gases, it is apparent that the economics involved vary greatly with individual installations. It is our aim to try and point out certain observations which we have made during the past few years with the hope that they will be of use to others in plotting the future course of process installations of polymerization units.

## DESCRIPTION OF PROCESSES

We may divide polymerization plants into two general classes based on the predominate product even though they may overlap: (1) aliphatic plants, and (2) aromatic plants.

The first type plants produce, in the main, aliphatic type polymer distillate, as the name implies. The distillate is low in the aromatics benzol, toluol, and xylol but is very high in the so-called chain compounds, olefins, and in naphthenes, which are ring compounds. The latter are often designated as Cyclo compounds. They are more stable than olefins and closely resemble the paraffins in physical and chemical properties.

The aromatics are compounds containing rings of six carbon atoms and are now made commercially from petroleum gases. Formerly, they were obtained from coal tar or from gas works as a by-product. Their importance cannot be overestimated for it is known that Germany built her chemical industry on aromatics as raw material, and her huge and efficient war machine as well. Some years ago I was told that there were listed at that time over 750,000 chemical compounds which had been made, isolated, and tested, all coming from coal tar as raw material. The same possibilities are latent in the development of petroleum chemistry.

The double classification of polymerization plants is an academic one since one plant can easily be designed and built which will make both classes efficiently. The aliphatic installations have been made by Universal Oil Products, Polyco, and Alco-Pure Oil Company. The Universal plant differs from the so-called thermal plants of Polyco and Alco-Pure in that phosphoric acid catalyst is used and the reaction temperature is about 400-500°F. as compared with the thermal plant's 950-1100°F. temperature. The Universal plants, however, convert only unsaturates, olefines, to liquid polymer whereas the thermal plants convert saturates as well. The catalytic type plants, even though they operate at lower temperatures, have the expense of the catalyst to be considered.

## AVAILABLE CHARGING STOCKS

For good yields the present polymerization plants require a charge stock having at least three carbons, propane-propylene, to the molecule, but they do not convert gases of one carbon atom and only partially those of two carbon atoms to the molecule. Higher yields of distillate are obtained from a $C_4$ charge stock, butane-butylene, than from any other lighter stock.

The first problem to be solved by a prospective purchaser of a polymerization plant is the one of charge stock. From our experience, gained by building and investigating the economics of a large number of polymerization plants, we believe it is uneconomic at present to attempt to install a polymerization plant unless at least 1500 barrels of charge stock, containing at least 75 percent $C_3$ and $C_4$ compounds are available.

Individual cases vary widely and one must consider carefully all the facts surrounding the case. As an example, if a refiner does not have an efficient high-pressure-gas-recovery plant, and he wants to make polymer gasoline, he is faced with an outlay for the gas-gasoline recovery plant which is the major cost in the installation of a polymerization plant. This fact should be stressed as it is believed that many people still regard polymerization as a complicated process. It is the opposite, in fact, for the process is just about as simple as any process ever installed by a refiner. Perhaps it is thought that the process is involved because of the auxiliary equipment which is necessary to prepare the charge stock

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and to separate the unconverted gases for recycle purposes. Reduced to simple terms, a polymerization plant consists of a tubular heater and a reaction coil. All other equipment is auxiliary. If a refiner has a modern high-pressure-gas-recovery plant, he has very little equipment to install in order to produce polymer distillate, i.e., essentially a furnace and a reaction coil followed by a fractionating tower. The cost of a plant, then, depends mostly on the cost of the recovery plant to produce fresh feed for the polymerization unit and not on the unit itself.

We turn now to the refiner who has no modern high-pressure-gas-recovery plant and who is now forced to install such a plant because of low earnings and competition. One example which we may cite is as follows:

The refiner found it would cost $100,000 to install a modern gas recovery system working at 125 pounds pressure. By expending $140,000, an increase of $40,000, he found that he could install a plant which would work at 300 pounds pressure which would not only prepare poly charge stock but would also recover unconverted charge for recycle. The increase cost of 40 percent covers all equipment necessary to install a "high-propane and butane-recovery plant" instead of a "high-butane-recovery plant." In addition to this feature, the new plant handles all refinery gases whereas the high-butane-recovery plant handled only butane-rich gases and not general refinery gas. To a large degree, the economics of polymerization are affected primarily by whether or not a refiner is going to spend money on a gas recovery plant regardless of his interest in polymerization or whether he already has a modern plant which can be readily converted to work at 300 pounds pressure. If these conditions exist, then it costs relatively little more either to build or rebuild as the case may be so that a high recovery of propane will be possible.

The cost of polymerization equipment is relatively low. In general such a plant consists of a charge tank, pumps, furnace, reaction coil, and a fractionating tower of simple design. The gas recovery part of the plant, which may already exist, is really the expensive part of a plant.

We have another set of conditions which are worth our careful consideration when contemplating the installation of polymerization plants. We refer to the possibilities of combining polymerization with other refinery operations such as reforming, cracking, etc. In a number of cases the picture is greatly improved when this combination can be effected. The gas-recovery systems necessary for reforming and cracking are generally such that with a small additional expenditure we can make polymerization a profitable operation where it would otherwise never pay out.

There are some cases where one can afford to junk existing gas-recovery plants because they are uneconomical to operate due to their high utility consumption and general inefficiency. The savings resulting from the installation of new and efficient gas-recovery plants makes it profitable to save enough in operating costs to pay out the polymerization plant in a shorter time.

Most refineries have stabilization and absorption gas-recovery plants today, but in many cases they are built to operate at too low a pressure to enable them to make a high-propane recovery and make the use of polymerization economical thereby. It is realized, of course, that after propane has been removed from the plant units, the operating pressure can be dropped. This makes it possible, in a number of cases, to use a great portion of existing gas-recovery plants in the new scheme embracing polymerization.

## OPERATION COSTS OF A THERMAL PLANT

We assume that conditions are favorable to the installation of the physical poly plant equipment and we now come to the operation of the plant. We have developed some generalizations and short cuts which may aid in computing operating costs of such a plant. While no fast rule can be laid down, the figures may be of service.

For an aliphatic polymer distillate, one may assume that its Btu content per gallon is 132,500 or 20,400 Btu's per pound. If we assume the fuel value of the gas (both charge and residue gas) to be one cent per therm (100,000 Btu) then the product distillate costs 1.32 cents per gallon or 55 cents per barrel. (This is really the value of the raw charge entering into the formation of poly distillate.) We start with $C_3 - C_4$ raw material and end with residue gas, poly distillate and gas oil. The Btu's in the distillate are important, for this is our main salable product. The operating costs, including utilities, operators, electricity, raw materials, maintenance and supplies, vary from 35 to 50 cents per barrel of distillate produced. This is added to the fuel value of the raw charge material. There is included no charge for taxes, depreciation, interest, or fixed charges. About half the 35 to 50 cents item is fuel. If the yield of distillate is low, then the costs go up in proportion and vice versa, therefore, the total cost is $0.90 to $1.05 per barrel without fixed charges.

Assume Grade B gasoline, 70-72 octane, is worth 5.3 cents per gallon. We find that the poly gasoline produced under these conditions is worth a 1.0 to 1.5 cent premium or 6.3 to 6.8 cents per gallon or $2.65 to $2.86 per barrel, therefore the gross profit is approximately $1.75 to $1.81 per barrel.

One may ask what the yield is when working on saturates such as propane as compared with the unsaturates propylene, etc. We find that the saturates give about 60 percent of the yield obtained when working on unsaturates.

Another item which affects the possibilities of making a profit from thermal poly operations is the one of recycle ratio. If the conversion is low per pass and it becomes necessary to stretch out the cycle ratio too far, no profit can be made by polymerization because of the increased investment and operating expense.

## PRODUCTION AND CHARACTERISTICS OF VARIOUS POLY DISTILLATES

It may be of interest to mention some of the characteristics of the distillate from various processes. The product from the Universal Oil Products Company's phosphoric acid process is mostly olefines which is to be expected. The reaction as reported by Ipatieff is essentially one of addition—one olefin to another olefin giving a liquid compound with twice the molecular weight of the raw material. This is actually the case. The Thermal Processes of Polyco and Alco-Pure Oil, however, give a product which is not the result of simple addition. Since they operate at pyrolysis temperatures, it is to be expected that many reactions take place, some desirable and others highly undesirable. The catalytic process of Universal, however, has one advantage and that is selectivity as to the product produced. The catalytic idea is worth considering for by such similar means it is now the hope to produce what are commonly called

"tailor made hydrocarbons." The industry has been studying the possibilities of hydrocarbon chemistry from the standpoint of how these new products will perform in a gasoline motor. The promising ones can be synthesized from the $C_3$ and $C_4$ hydrocarbon gases if the proper catalyst and technique are developed. An example of this is isooctane. A laboratory curiosity for years, it is now an article of commerce within the price air-craft can afford. It is well known that this compound is made from butylene, a refinery cracking still by-product. Here we have a case of catalysts playing a major role—sulphuric acid or phosphoric acids, as the case may be—and the result is not duplicated by thermal means alone.

The production of isooctane on a commercial scale is of more than ordinary interest for it has verified, at least, certain chemical theories of polymerization. The production of technical isooctane, with an octane rating of 93-97, on a commercial scale by the Shell Oil Company, and others, by means of reacting $C_4$ hydrocarbons, as a mixture, of olefins and paraffins, showed that a high percentage of the normal butylene was converted to a liquid, probably by what is known as interpolymerization, i.e., a part of the normal butylene reacts with the isobutylene to form a polymer, which, when hydrogenated, yields an octane of good anti-knock value. By this reaction, the yield of technical isooctane from petroleum gases has been doubled. In this process hot sulfuric acid may be assumed to play the part of a true catalyst.

The cold-acid process as outlined by McAllister of Shell Oil Company is still the best method for the production of pure isooctane. Inasmuch as its anti-knock value is 100, by definition, and the value of the hydrogenated polymer made by the hot-acid process is as high as 93-97, the advantage from an economic standpoint is in favor of the hot-acid process.

The phosphorous compounds function in a similar manner to the sulfuric acid—they are catalytic but it is necessary to react the hydrocarbons at 400-500° F. instead of 100-250°F. which is used in the sulfuric-acid process. Other catalysts such as the metallic oxides like those of the elements aluminum and chromium have properties similar to the phosphoric and sulfuric acids.

We may classify the present commercial polymerization processes in the following manner, depending on the three major elements which enter these processes: (1) nature of charge stock, (2) method of polymerization, and (3) products made.

If we start with petroleum gases or low molecular weight hydrocarbons from natural gas ($C_3$ and $C_4$ hydrocarbons), we must first process the raw material to produce a selected charge stock which will yield the product desired by the process at hand. If we wish to produce a motor fuel blending stock, aliphatic polymer, we can separate the $C_3$-$C_4$ fraction of refinery gases and either thermally polymerize this out directly or we can make use of catalysts. Both methods can be made to produce about the same quality and quantity of polymer.

If we wish to produce aromatic hydrocarbons such as benzol, toluol, and xylol, we charge the same raw material but by the thermal process we operate at temperatures in the range of 1150-1300°F. instead of 950-1100°F. and we employ lower pressures than we do when making aliphatic distillate. Laboratory work indicates that aromatics can be produced from olefinic charge stock by catalytic means. This work, however, is not ready for commercial application.

If we desire to make technical isooctane we must further segregate our charge stock into a narrow fraction consisting exclusively of $C_4$ hydrocarbons. The thermal process is not satisfactory to produce the dimer which is later hydrogenated to the octane. We must rely upon the acid or oxide catalysts entirely at the present time.

The above schemes all operate on olefines as the original raw material. The other variable in processing is the introduction of pyrolysis into the process. By subjecting the paraffins such as propane and butane to pyrolysis, we can attain a high yield of olefines which are then charged to the poly plants for the production of any of the three major types of liquids mentioned, (1) aliphatic, (2) aromatic, or (3) dimer in the production of isooctane.

## PRODUCTION OF OLEFINES

An interesting phenomenon appears when we charge paraffins for the purpose of producing olefine gases, i.e., considerable quantities of aromatics are produced as a by-product of the pyrolysis operation. If a refiner desires to produce olefines such as ethylene, propylene or butylene from propane or butane, it is necessary to pyrolyze them at temperatures ranging from 1150-1350°F.—a temperature range favorable to the formation of aromatics. As would be expected, relatively large amounts of benzol, toluol, and xylol appear as polymerization products resulting from the soaking of the pyrolyzed gases which is unavoidable in commercial units. The pyrolysis operation is favored by low pressure but it is necessary to have some pressure in the furnace tubes in order to have the required flow of gases through the tubes and this, of course, results in some soaking. In other words, it is practically impossible from an economic standpoint to employ low enough pressures, with low time intervals, to prevent entirely the polymerization of some of the olefines to aromatics.

Some interest has been shown in a process to use crude oil as charge stock for the production of olefines and aromatics. We have found it possible to crack reduced crude oil and then pyrolyze the saturated gaseous hydrocarbons above ethene to aromatics or to olefines and aromatics. There is also data on hand to show that ordinary gas oil will yield about 4 percent of isooctane and at the same time produce some aromatics and other olefines. It is only the question of economics which is holding these processes in reserve.

By present methods it is necessary to crack 100,000 barrels of charging stock such as gas oil or reduced crude oil, to produce, as a by-product, enough butylenes to yield 750-800 barrels of isooctane.

Say 60 percent PD yield on Gas Oil Charge
= 60,000 bbls. PD
Say 15 percent of PD i.e. $C_4$—$C_4$
= 9,000 bbls. $C_4$—$C_4$
Say 30 percent (high) of $C_4$—$C_4$ is Isobutylene
= 2,700 bbls. Iso $C_4$
Say Conversion 90 percent
= 2,430 bbls. Converted
Say Volumetric ratio $C_4$ to $C_3$ is 2:1
= 1,215 bbls. $C_3$

Methods now exist, however, which double this yield but the cost of the isooctane also doubles because of the low value of the by-products made by the pyrolysis operation. The production of aromatics on a commercial scale is now a fact but the magnitude of this business depends upon how much the refiner can get for premium octane fuel, since aromatics are economically obtained in sufficient

quantity from coal to meet peace-time chemical needs. Any phenomenal production of aromatics from petroleum for chemical purposes would seriously upset the coal-tar aromatic market.

### QUALITY OF ALIPHATIC DISTILLATE

Considerable work has been done with the view of ascertaining the true composition of the aliphatic polymer distillate. The following break-up appears to be reasonably correct:

**CHEMICAL COMPONENTS OF POLYMER DISTILLATE**

| Boiling Range °F. | Compounds |
|---|---|
| 70-100 | Pentene (1—) |
| | Pentene (2—) |
| | Pentane |
| | Methyl-butene |
| | 1 4 Pentadiene |
| 110-145 | Cyclopentene |
| | 2-2 Dimethylbutane |
| | Dimethylbutene |
| | Cyclopentane |
| | Methyl-pentane |
| 145-200 | Hexane |
| | Methyl-cyclopentane |
| | Benzol |
| | Dimethyl-pentane |
| | Cyclohexadiene |
| | Cyclohexene |
| | Ethylmethylbutene |
| | Dimethylcyclopentane |
| | Methyl-hexene |
| 200-240 | Methyl-cyclohexane |
| | Heptane |
| | Heptene (2—) |
| | Ethyl-cyclopentene |
| | Dimethyl-hexane |
| | Toluol |
| | Methyl-heptene |
| | Cycloheptane |
| 240-302 | Ethyl-hexane |
| | Octane |
| | Ethyl-cyclohexane |
| | Xylene (o—) |
| | Xylene (p—) |
| | Xylene (m—) |
| | Ethyl-heptane |
| | Ethyl-cyclohexene |
| | Octene |
| | Nonene |

The above compounds were identified through their specific gravity, boiling point, and refractive indices, on 1 percent cuts. Certain tests such as bromination, nitration, sulfonation, etc., were made to identify the structure of the hydrocarbons. The thermal polymer distillate consists of approximately this composition:

40 percent Paraffins
40 percent Olefins
10-20 percent Aromatics
5 percent Naphthenes

When operating at higher temperatures and at lower pressures (100-300 pounds) and with recycling, there can be obtained a polymer distillate of 89-91+ octane containing over 70 percent aromatics and of such a nature that a good fractionating column will separate commercial cuts of benzol, toluol, and xylol.

It is interesting to note that by acid treating cuts from this polymer, there is obtained a product which is higher octane than the crude polymer cut, i.e., the aromatic compounds remaining after acid treating are higher in octane value than the mixture of olefins and aromatics; the olefins are absorbed by the acid, and the remaining product is 92-94 octane value (CFRM). It is a common conception to think of acid treating as a process which degrades the distillate in octane value.

### SUPERFRACTIONATION OF POLY DISTILLATE

Work on fractionating columns during the past 10 years has resulted in columns which will separate hydrocarbons some 5 to 10 fold as efficiently as formerly. This has made commercially possible the production of valuable hydrocarbon cuts of very high octane value from gasoline, cracked distillate and from polymer distillate. By running a still on Mid-Continent straight-run gasoline so that cuts are made every few degrees, and by separating the poor octane hydrocarbons from the good and reblending the "peaks," it has been found possible to obtain 10-35 percent of aviation base gasoline of 74-77 octane value. By applying the same technique to polymer distillate it is possible to separate cuts of very high octane value and to make cuts which are easily treated to obtain individual commercially-pure aromatics such as benzol, toluol, and xylol. The art of super-fractionation is in its infancy and it is to be hoped that many new synthetic substances will result partially as a result of the application of this technique.

The mechanism of the formation of the conjugated dienes, such as butadiene, has not been proved, but some of the postulates are very useful in carrying on research work. Some workers hold that the dienes are the intermediates in the formation of aromatic hydrocarbons by pyrolysis. Other investigators doubt that aromatic formation passes through the conjugated open chain molecule stage.

It is known that aromatics are produced by vapor-phase cracking at temperatures around 1100-1200°F. and tests made on the products of these reactions indicate dienes. They are never found in high percentages, however, for they are so reactive that they form other substances if the reaction time is not held to a fraction of a second. Since the reaction is bimolecular in forming aromatics from conjugated dienes, low pressures do not favor such reactions. We find that pressures in order of 300 pounds pressure are a practical compromise in this work. It is also true that the high percentage gasification of a gas oil in pyrolysis favors the formation of dienes and aromatics. By employing this technique it is possible to commercially produce aromatics and dienes from petroleum. This process is very interesting and it will be still more interesting to follow this particular development during the next few years. Since we can now obtain, by one process, a liquid from the pyrolysis of petroleum containing above 50 percent conjugated dienes, the manufacture of chemical products from these very active materials is but a short step to be taken.

### NATURAL GAS AS A RAW MATERIAL

Few people in the past have realized the cheapness of natural gas as a chemical raw material. The heavier constituents of it, such as butane-isobutane, have proved valuable raw materials for pyrolysis. The isobutane, particularly, is a good material for pyrolysis to high octane polymer gasoline. The probable explanation of why high yields of gasoline are obtained is that the isobutane dehydrogenates and loses methane and results in a high yield of propylene with very little ethane formation. The propylene and butylene give almost theoretical yields of polymer with good catalysts. The thermal decomposition of isobutane at low pressure also favors the above reactions. High pressure pyrolysis of isobutane gives a

relatively high yield of ethane. One disadvantage with working at 300 pounds pressure is that ethylene is not polymerized to any large degree whereas at high pressures it is transformed into polymer gasoline. For the production of isobutylene, the pyrolysis of isobutane gives the highest yield of any known substance. This reaction is economically attractive for the manufacture of isooctane.

### CONCLUSIONS

1. A refiner who has to spend money on his gas plant can almost always justify polymerization.

2. Poly distillate can be treated with cracked distillate. It is best to cut cracked distillate into light and heavy if acid is necessary. The poly is clay treated or acid treated with heavy distillate. Caustic wash light distillate.

3. The volatility of poly is often an asset for blending purposes. It will show 60-70 percent off at 212°F.

4. Sulphur removal is necessary if $H_2S$ is over 50 grains per hundred cubic feet. 150-200 grains per 100 cubic feet should utilize some process for $H_2S$ removal.

5. If cracking plant gas has excess butanes the refiner can get 10 percent more gasoline if poly plant is installed.

| Volume percent $H_2S$ | Grains per 100 cu. ft |
|---|---|
| 1.0 percent equivalent | 600 |
| 0.1 percent equivalent | 75 |

### PHOSPHORIC ACID PROCESS COSTS

1. Costs per gallon of poly distillate have been reported as two cents per gallon for catalyst alone which makes it appear an expensive process.

2. Flue gas revivifications have to be cool and the water separated. Water makes the acid corrosive and ammonia is needed to prevent corrosion.

### BLEND VALUES

The blending value of the poly distillate is 100 when 5 percent is blended with 62 octane gasoline, this as determined by the L-3 method.

### CONVERSION PERCENTAGE

The refiner when manufacturing a poly distillate of 10 pound R.V.P. and 400°F. E.P. may expect the following conversion.

49 percent by Wt. on propane
80 percent by Wt. on propylene
60 percent by Wt. on butane
85 percent by Wt. on butylene

Tests on a poly gasoline are as follows:

| | |
|---|---|
| Gravity °A.P.I. | 51.7 |
| Color | 23 |
| Sulfur | 0.01 |
| Copper dish gums | 18 |
| Glass dish gums | 7 |
| Initial B.P. °F. | 94 |
| 5 percent recovery | 130 |
| 10 percent recovery | 142 |
| 20 percent recovery | 159 |
| 50 percent recovery | 193 |
| 90 percent recovery | 336 |
| E.P. °F. | 416 |
| Percent recovered | 96 |
| Oct. No. Motor Method | 80 |
| Reid Vapor Pressure | 10.8 |

In blending with a straight motor gasoline of 398 end point, 2 pounds Reid V.P., and 64 octane number by the motor method we get the following:

| | | | | | |
|---|---|---|---|---|---|
| Percent straight run | 100 | 90 | 80 | 70 | 0 |
| Percent poly | 0 | 10 | 20 | 30 | 100 |
| Octane No. | 64 | 68 | 71 | 73 | 80 |

In blending the same straight run with 22-pound California natural of 21.8 pounds V.P. and 80 octane number, we got:

| | | | | | |
|---|---|---|---|---|---|
| Percent straight run | 100 | 90 | 80 | 70 | 0 |
| Percent natural | 0 | 10 | 20 | 30 | 100 |
| Octane No. | 64 | 65.5 | 67 | 69 | 80 |

For lead susceptibility blends were made, 70 percent straight run and 30 percent poly marked "A," and 70 percent straight run and 30 percent natural marked "B," with following results:

| | "A" | "B" |
|---|---|---|
| Octane Number | 73 | 69 |
| 1 cc per gallon t.e.l. | 78 | 76 |
| 2 cc per gallon t.e.l. | 81 | 80 |
| 3 cc per gallon t.e.l. | 82.5 | 83 |

We have not yet run the induction period, nor a low pressure fractional analysis to determine butane content.

# Burners

[*Continued from page 324*]

12-section alloy bottom plate is suspended by alloy rods bolted to the top of the wind box. In the center of the bottom burner plate is a manhole damper, which can be raised or lowered as required for additional air supply and also for heat-distribution control. The manhole damper is suspended from three points and can be tilted for additional control of heat distribution. The oil-burning feature of this combination oil-and-gas burner consists of three internal-mixing steam-atomizing oil burners equipped with drilled cone tips. When burning fuel oil only, the air nozzles and manhole damper are adjusted to provide heat distribution. The main advantage of this type of combination oil-and-gas burner is heat-distribution control at high capacity. The burner is also able to operate at low capacity with low excess air and satisfactory heat distribution. The main disadvantages are: The gas tips become plugged when using dirty gas, and high wind box and gas pressures are required. Although this type of burner has only been in operation for a short period of time, it appears that maintenance will be low, regardless of the high-temperature air used.

Figure 17 illustrates some of the various designs of oil burners and oil-burner tips used in conjunction with combination oil-and-gas burners.

There are other combination oil-and-gas burners available, which are equally as good as those illustrated in this paper, but lack of time and space prevents further illustrations. It is hoped that this paper will aid the combustion engineer toward a better understanding of the calculations of stack losses, when burning two or more petroleum fuels simultaneously, and aid the purchaser of gas-and-oil-burning equipment to make a more intelligent selection for any particular installation.

### ACKNOWLEDGMENT

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# *Recent* Improvements *in* Natural Gasoline Manufacture

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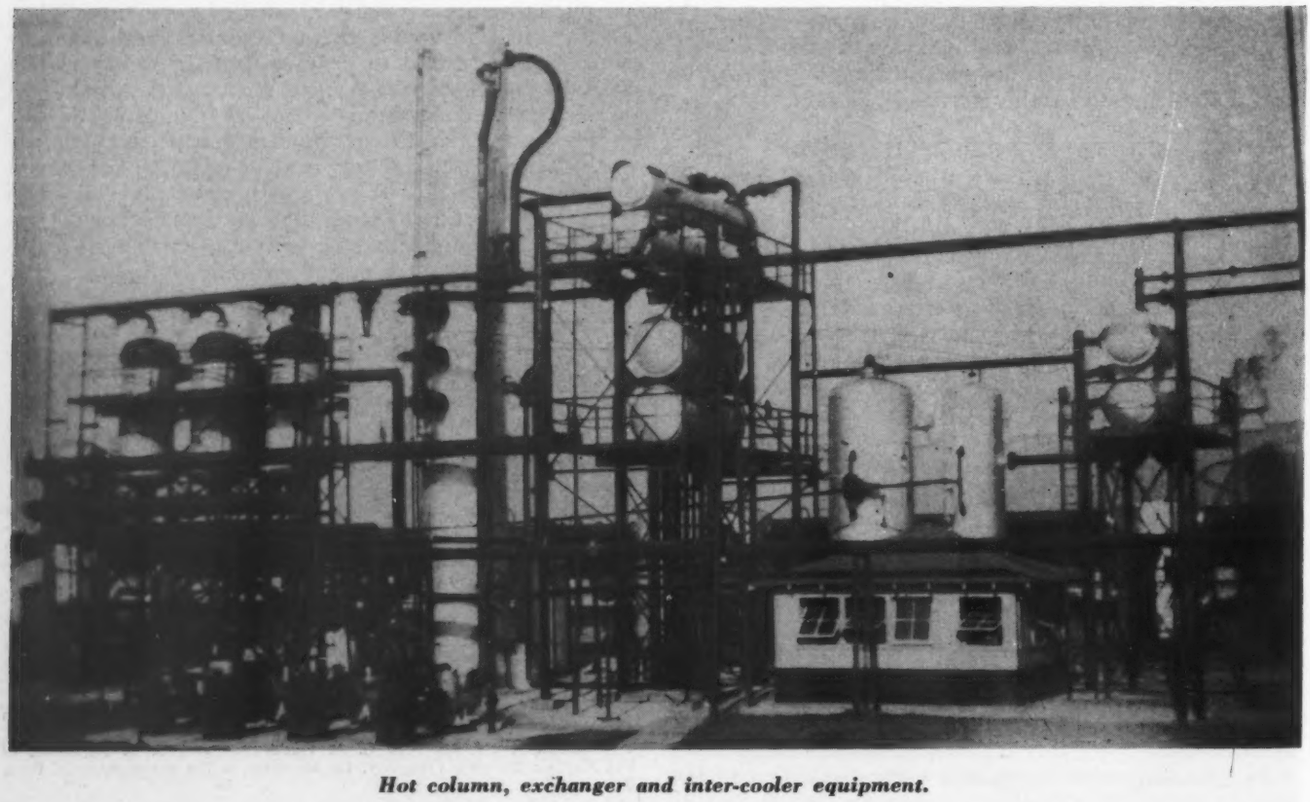
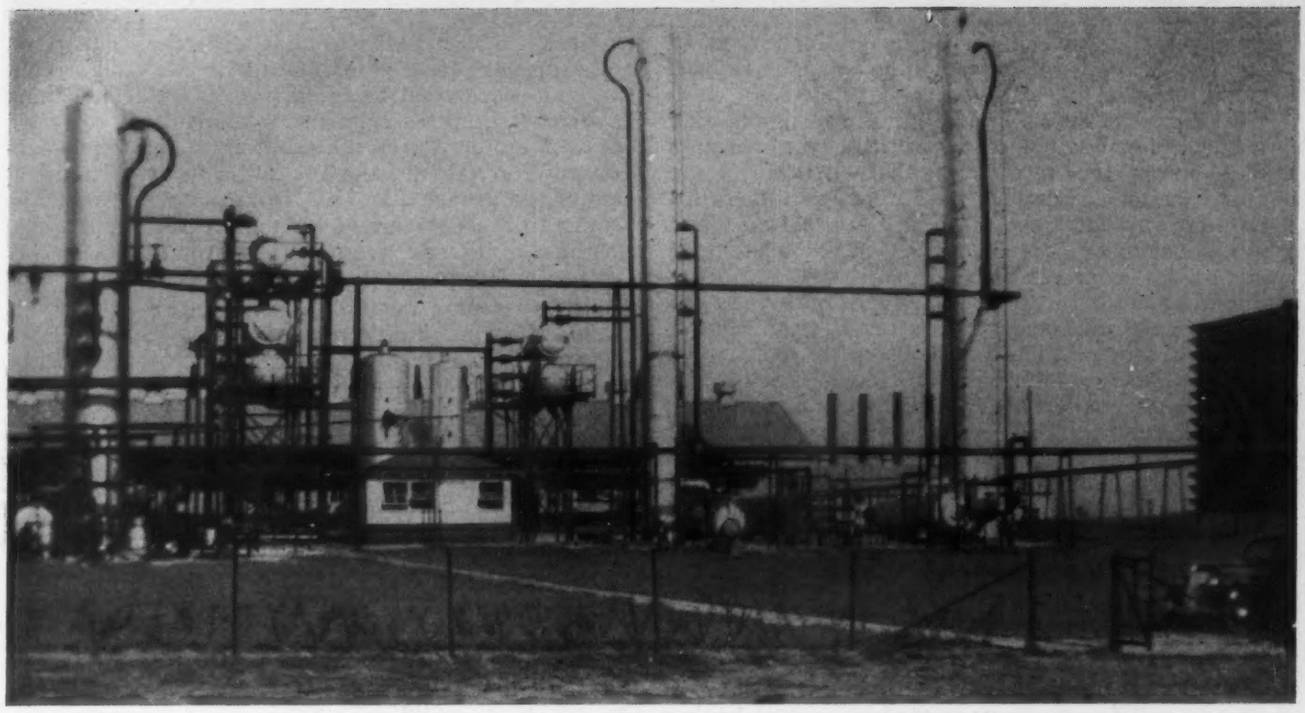
THE manufacture of natural gasoline in East Texas is an interesting study because of several characteristics peculiar to the East Texas oil field. First it is unusual from the field standpoint where one gasoline plant operates on gas taken from a large number of wells the majority of which make their allowed production in 15 to 30 minutes time, and which number tied into each plant would be a large oil field in itself. Another interesting feature is in the gas which not only is rich in gasoline but contains large quantities of butane and propane.

There are 13 large gasoline plants in the field and several small units. These plants are connected to the majority of the 25,000 wells in the field and produce in the neighborhood of 750,000 gallons of gasoline, butane and propane per day, or about 540,000 barrels per month.

The Sabine Valley Gasoline Company plant, which is located four miles north of Kilgore, Texas, began operating on April 22, 1935, and has been operating continuously since that time with the exception of two shut-down periods, 12 hours in 1936 to tie in an additional unit, and 2 days in 1937 to tie in additions for the production of butane. This plant was constructed in record time of three months under the direct supervision of H. R. Dickerson, president of the company. The plant is capable of processing 12,000,000 cubic feet of gas per day producing 60,000 gallons of 26-pound natural gasoline and 50,000 gallons of butane-propane mixture. The present equip-



***Hot column, exchanger and inter-cooler equipment.***



*Sabine Valley Gasoline Company, Inc., plant near Kilgore, East Texas field, employing the vapor rectification process for gasoline extraction.*

ment is designed to manufacture a butane mixture containing 10 percent propane, but provisions have been made for the installation of additional equipment to recover 70 percent of the propane available in the wet gas.

## FIELD SYSTEM

It is a general practice for the oil producers to flow all their oil through one oil-and-gas separator centrally located on the lease. One separator handles as many as 40 wells although most of the larger leases have more than one separator. These separators are usually elevated so that the oil will flow by gravity into the stock tanks and atmospheric pressure or less may be maintained on the separator. This is an advantage to the gasoline-plant operator in that a higher gas/oil ratio and a richer gas is thus obtained.

The Sabine Valley Gasoline Company pipe line system consists of about 75 miles of pipe ranging from 20-inch to 4-inch diameter. The system branches out from the plant and connects to the vent lines from the separators on the leases. Paralleling these gathering or wet gas lines which operate under a vacuum is a pressure system which returns the residue or dry gas back to the producer for leases operations.

The gas from the vent line is measured by an orifice meter and passes through a regulator which is set to maintain sufficient pressure on the separator to dump the oil into the stock tanks. In most cases the separators are elevated so that atmospheric pressure is required while other separators on the ground may require as much as 8 or 10 pounds pressure. Under these low pressures there are practically no vapors coming off the oil storage tanks, and no connections have been made to the vapor space of these tanks. The weighted average separator pressure maintained on the leases is less than one pound.

On the west side of the field, a number of the wells are producing salt water, making it necessary to treat the oil, which is usually done by heat, although in some cases chemicals or a combination of chemicals and heat is used. Where heat is used the treatment is done in several ways. The older custom is to flow the oil from the separator into a settling tank or gun barrel, where the required heat is obtained by circulating the salt water from the bottom of the gun barrel through an ordinary boiler. In this way the rich vapors driven off by the heat treatment are lost unless the gasoline plant operator connects onto the top of the gun barrel. Another practice is to flow the oil into a combination heater-separator in which case the rich vapors go off with the usual gas and is received into the gasoline plant. A third method is that of flowing the oil through a heater before going to the separator, which heater may be a boiler or may just be a heated pipe coil, and the gasoline plant benefits also by this treatment.

In order to keep a uniform supply of gas coming into the gasoline plant throughout the day and night, it is necessary that a definite time schedule be worked out for these wells to flow under, and the maintenance of this schedule speaks well for the cooperation obtained from the producers and lease operators. This schedule is usually arranged so that a producer will alternate his leases between day and night flow, or one producer may alternate with another producer.

## PLANT FLOW SHEET

The process employed by the Sabine Valley plant is the vapor rectification process, operating under Petroleum Engineering, Inc., patents, which consists essentially of compressing the wet gas up to a required pressure and passing into an ordinary fractionating column or stabilizer (or hot column, as it is sometimes called), where the gasoline product is taken from the reboiler and gas passed out the top through coolers for condensing reflux.

In order to recover a high percentage of butane in the product, it is necessary to operate the column at lower temperatures than found in an ordinary

vapor rectification plant. Since reflux is condensed at a temperature lower than can be obtained by using water as a cooling medium, boiling propane is used for this purpose.

The process is shown in detail in the accompanying flow sheet. The wet gas comes into the plant through four master meters into two tanks, where any large quantity of oil is removed, and on to scrubbers for extracting any entrained oil. The compression plant, which consists of 12 twin, direct-driven gas-engine compressors, compresses the gas from 10 inches mercury vacuum to about 40 pounds gauge in the low stage, and discharges into a scrubber to remove any compressor oil. The intercoolers are maintained at a temperature which will sufficiently cool the gas but minimize condensation, since gasoline obtained here is off-color and no provision has been made for treating this product. From the intercooler gas scrubber, the gas is compressed to about 285 pounds pressure and discharges into a scrubber and then on into a water-cooled gas cooler and a gas exchanger which further cools the gas to about 85°F. before entering the recovery column. This column is a standard fractionating column 60 inches in diameter and contains 24 bubble cap trays and operates at 275 pounds pressure.

A temperature of about 220°F. is maintained in the reboiler. This temperature gives a product having a vapor pressure of about 65 pounds Reid, and which contains practically all of the butanes and an excess quantity of propane which is later removed. No appreciable amounts of methane or ethane are present.

The gas from the top of the column passes through three vertical condensers operating in parallel to condense the reflux necessary for the column's operation. The uncondensed vapors, or dry or residue gas, which is cooled to about 42°F., passes through the gas exchanger cooling the wet gas. From the exchanger the residue gas passes through a back pressure valve operating to hold a constant pressure on the recovery column. The gas then enters the field residue-gas system, whose pressure is maintained at 175 pounds by venting off and burning the unused gas.

It has been found that the quantities of water vapor in the wet gas will form hydrates at the low temperatures required in the condenser tubes, and which greatly decrease the condenser efficiency. A water trap has been placed on the feed line between the gas exchanger and the recovery column, and removes a considerable amount of water that would otherwise be carried over into the reflux condensers. It is also necessary to periodically allow the reflux condensers to heat up for about 10 minutes to "defrost," or thaw out these hydrates.

Since practically all of the butanes are recovered in the recovery column bottoms, propane must be condensed for reflux. This can be done by cooling the overhead vapors down to about 42°F. and which temperature is obtained using boiling propane as a cooling medium. The system is designed to use propane as a refrigerant because practically pure propane is available in the reflux stream over the depropanizer column. This propane circulates in a closed system which consists of compressing the propane gas to about 200 pounds, at which pressure it is condensed in water-cooled condensers, and is collected in a tank. From the propane tank the liquid passes through an exchanger and is fed into an expansion tank, which is merely a common vessel connected to each condenser at the bottom for the liquid to enter and at the top for the vapors to escape. The expansion tank is at the same level as the condensers, and a propane level is maintained in the tank so that the condensers will be filled with liquid. This tank, as well as the three condensers, is insulated to retain the cold temperatures. The cooling in the reflux condensers is obtained from the latent heat of vaporization of the propane, and not from the expansion. The temperature is governed by the back pressure held on these units, and averages about 60 pounds.

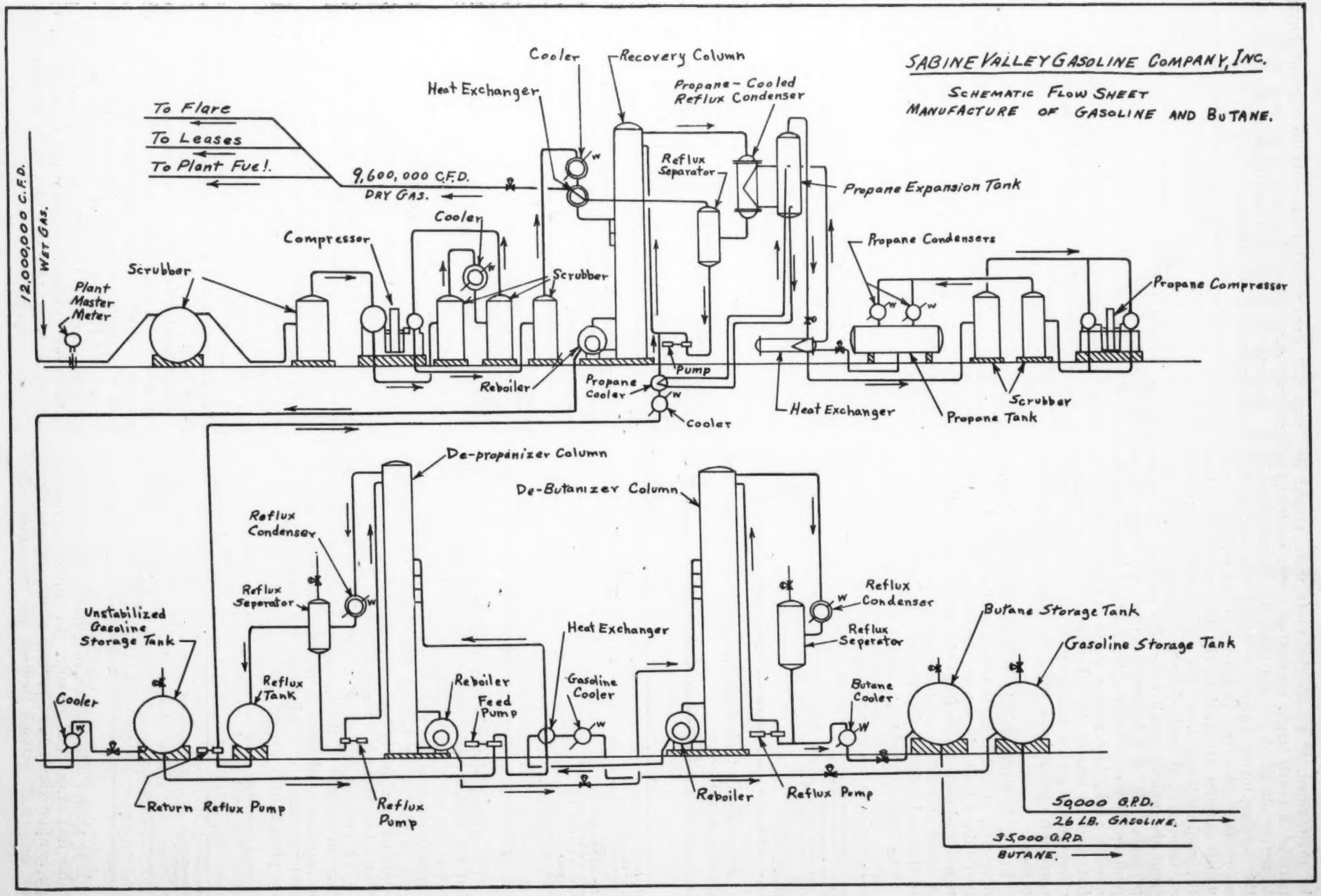
The gasoline and butane-propane mixture from the reboiler pass through coolers into a surge tank, which takes up slight variations in the load so that a constant feed rate may be had for the stabilization units. As stated before, this product contains an excess quantity of propane, which is later removed. Specification product could be made on the recovery column, if there were no variations in the wet-gas load, but since every change in the load alters the equilibrium in the column, it is advisable to make a higher vapor pressure product here and stabilize in a second step.

The unstabilized mixture is pumped through a heat exchanger into the depropanizer fractionating column. This column is 42 inches in diameter and contains 30 trays, and is now operating at 225 pounds pressure. All of the overhead vapors are condensed, and the excess liquid flows into a reflux tank. The normal reflux rate used in the depropanizer is about six mols reflux to one mol excess reflux. This excess reflux is pumped from the reflux tank through a water-cooled cooler and a propane-cooled cooler so as to lower its temperature to the same as the recovery reflux stream with which it is mixed as needed. A flow controller measures the total reflux pumped into the recovery column and operates the excess reflux pump. A liquid-level control on the recovery reflux separator operates a pump so that this reflux is all pumped directly into the column. These two reflux streams give a ratio of about one half mol reflux to one mol dry gas.

The depropanizer reboiler is operated at 220°F., which temperature may be varied to adjust the amount of propane required in the butane-propane product. The reboiler product passes directly into a debutanizer fractionating column, which is 66 inches in diameter, contains 30 trays, and is now operated at 150 pounds pressure. This fractionates out the remainder of the propane and the excess butanes not required in making the desired vapor pressure gasoline. All of the overhead vapors are condensed and the excess liquid passes through a cooler and on to the butane propane storage tanks. A reflux ratio of about three mols reflux to one mol overhead product is maintained.

The butane propane product and the natural gasoline are sold to Hanlon-Buchanan, Inc., which pumps these products from the tanks into its pipe line gathering system.

The auxiliary equipment consists of steam-driven centrifugal water pumps and an electric generator. Water supply is obtained from three deep wells operated by gas lift. This water goes directly into the distillation water-cooling tower pit from which pumps circulate it through the closed-type coolers and bask over the louvre-type cooling tower. Most of the coolers on the fractionating equipment are connected in series so that the coldest water goes where the lowest temperatures are required, and then goes to other coolers where higher temperatures may


SABINE VALLEY GASOLINE COMPANY, INC.
SCHEMATIC FLOW SHEET
MANUFACTURE OF GASOLINE AND BUTANE.
Cooler
Recovery Column
Heat Exchanger
Propane - Cooled Reflux Condenser
To Flare
To Leases
To Plant Fuel
9,600,000 C.F.D.
DRY GAS.
12,000,000 C.F.D.
WET GAS.
Reflux Separator
Propane Expansion Tank
Cooler
Compressor
Scrubber
Plant Master Meter
Scrubber
Propane Condensers
Propane Compressor
Pump
Reboiler
Propane Cooler
Cooler
Heat Exchanger
Propane Tank
Scrubber
De-propanizer Column
De-Butanizer Column
Reflux Condenser
Reflux Separator
Unstabilized Gasoline Storage Tank
Heat Exchanger
Reflux Condenser
Reflux Seperator
Butane Storage Tank
Gasoline Storage Tank
Cooler
Reflux Tank
Reboiler
Feed Pump
Gasoline Cooler
Butane Cooler
Return Reflux Pump
Reflux Pump
Reboiler
Reflux Pump
50000 G.P.D.
26 LB. GASOLINE.
35000 G.P.D.
BUTANE.

be maintained. If all of the units were placed in parallel, a much larger amount of water would have to be circulated. A control holds a constant level in the cooling-tower basin by letting the excess hot water flow into the jacket-water-hot-well pit, and which amount is equal to the well-water flow less the cooling-tower loss. The jacket-water system is an open system with the water flowing by gravity from the storage tank over the engines and compressors into the hot-well pit, from where it is pumped back over an elevated cooling tower into the storage tank. Any excess water overflows from the hot well to waste. An alkaline solution of sodium chromate is added to the well water to minimize corrosion caused by a small amount of free oxygen present.

Steam is generated in five oil field-type boilers operating at 150 pounds pressure. Boiler-feed water is obtained from the return steam system plus additional make-up taken from the engine hot-well pit. A small amount of monosodium phosphate is added to the feed water to limit caustic embrittlement.

The following table shows the plant utility data:

| | |
|---|---|
| Field Compressor horsepower | 2,760 |
| Propane compressor horsepower | 460 |
| Boiler horsepower | 438 |
| Distillation unit water circulation | 2,100 g.p.m. |
| Jacket water circulation | 2,100 g.p.m. |
| Butane-propane storage | 100,000 gal. |
| Gasoline storage | 100,000 gal. |

An analysis typical of the gas coming into the plant is as follows:

| | Percent Mol. | G.P.M. |
|---|---|---|
| Methane | 40.96 | ..... |
| Ethane | 15.97 | ..... |
| Propane | 22.29 | 6.13 |
| Iso butane | 4.01 | 1.30 |
| Normal butane | 10.05 | 3.18 |
| Iso pentane | 2.67 | 0.97 |
| Normal pentane | 1.96 | 0.63 |
| Hexanes | 1.29 | 0.53 |
| Heptanes and heavier | 0.80 | 0.37 |
| | 100.00 | |

The composition will vary somewhat over the field, but the atmospheric temperature and the separator pressures have more effect on the heavier hydrocarbons since at the present time the gas is in solution in the oil at bottom hole pressures. The gas contains practically no sulphur, so no caustic or doctor treatment is necessary.

The present operation of the plant is to recover over 90 percent of the butanes and enough propane to produce a mixture of butanes containing 10 percent propane. An analysis of the residue gas from the plant is as follows:

| | Percent Mol. | G.P.M. |
|---|---|---|
| Methane | 52.96 | ..... |
| Ethane | 18.23 | ..... |
| Propane | 27.93 | 7.67 |
| Iso butane | 0.47 | 0.15 |
| Normal butane | 0.41 | 0.13 |
| | 100.00 | |

This shows 0.28 gallons of butanes per thousand cubic feet of dry gas, or since the volume of residue gas is approximately 80 percent of the wet gas, there are only 0.22 gallons butanes per thousand cubic feet wet gas, which represents 95 percent butane extraction.

An analysis of the butane-propane product being manufactured is as follows:

| | Percent Liquid Volume |
|---|---|
| Propane | 10.76 |
| Iso butane | 32.95 |
| Normal butane | 56.29 |
| | 100.00 |

An analysis of the 26-pound Reid natural gasoline from the plant is as follows:

| | Percent Liquid Volume |
|---|---|
| Iso butane | 1.05 |
| Normal butane | 31.61 |
| Iso pentane | 22.24 |
| Normal pentane | 19.08 |
| Hexanes | 16.42 |
| Heptanes plus | 9.60 |
| | 100.00 |

The A.P.I. gravity on the 26-pound averages about 90.9. The recovery at 140 Engler distillation averages 85 percent.

The operating conditions on the three columns are summarized in the following table:

| | Recovery Column | Depropanizer | Debutanizer |
|---|---|---|---|
| Operating pressure | 275 lb | 225 lb | 150 lb |
| Feed Temperature | 85° F. | 154° F. | 190° F. |
| Reboiler temperature | 220° F. | 230° F. | 236° F. |
| Top temperature | 70° F. | 118° F. | 174° F. |
| Reflux ratio | 0.5/1 | 6/1 | 3/1 |

The production data from the plant for March on the basis that there had been no Sunday shut-downs are as follows:

| | |
|---|---|
| Average daily gas | 10,917,000 cu. ft |
| Average 26 lb. daily production | 45,317 gal. |
| Average propane butane daily production | 34,247 gal. |
| Average total daily production | 79,564 gal. |
| Average oil flowed daily on leases | 33,432 bbl. |
| Average gas oil ratio | 327 |
| Average gal. 26 lb. gasoline recovered per bbl. oil | 1.355 |

## CONCLUSION

The vapor rectification type of plant is especially applicable to the type of gas in the East Texas field due to the large percentages of ethane, propane and butanes. When additions will be made to the Sabine Valley Gasoline Company, Inc., plant for the recovery of high percentage of propane, it will be necessary to condense ethane for reflux and this will require compressing the overhead vapors from the recovery column to approximately 700 pounds pressure before passing through the reflux condensers. The reflux obtained will be expanded into the top of the column.

The advantage of this type of plant is the installation cost and the ease and economy of operation. The process in itself is quite simple and requires a minimum of attention from the operator. The cost is low on account of the low water circulation and the low quantity of steam required. It is also an advantage to have high pressure residue gas available for the field where a saving is obtained in the smaller residue pipe lines required.

# Opportunities for Natural Gasoline

R. C. ALDEN
*Phillips Petroleum Company*

THE natural gasoline industry has a surpassing record of vigor, energy and courage. It is a remarkable achievement for an industry "sired by a roustabout and dammed by two-inch pipe" to have attained its present stature. Think of the advances that have been made: the oil absorption process, fractionation, Reid vapor pressure, the natural gasoline grading system, motor fuel blending, liquefied petroleum gases, blimps, tanker shipments, polymerization, and many others.

There is no doubt but that the natural gasoline industry will resume its vigorous record of achievement. Momentarily, however, we have sunk into the apathy of depression complexes. Practically all of our energy has been given over to the grim necessity of weathering the economic storms of hard times. That we have weathered the storms is proof enough that we are capable of industry, the final step in the sequence of events leading to constructive progress. But one is reminded of the maxim "All work and no play makes Jack a dull boy." We are too prone nowadays to consider our job is well done when we have survived another month.

The essential ingredients of progress are imagination, initiative, and industry. First, there must be the idea; second, a start must be made; third, there is the continued hard work of application. It is the purpose of this paper to demonstrate that imagination has not been dead. There are plenty of ideas awaiting development. There are numerous problems to be solved if natural gasoline is to retain its usefulness and value.

In the following paragraphs several of these ideas will be discussed; several of the problems will be reiterated. There is nothing particularly new about them except that perhaps they have been forgotten or overlooked.

In preparing this compilation considerable use has been made of the proceedings of the annual conventions of the Natural Gasoline Association of America. If you should reread these interesting documents you will most likely be impressed with the unanimity of opinion as to the most serious economic flaw of the natural gasoline industry. That flaw is the lack of adequate storage facilities for the proper marketing of a product in seasonal demand. Hence, it seems appropriate to first review this subject.

## SEASONAL STORAGE

Under almost any conceivable circumstances, natural gasoline has been, is and always will be confronted with a very serious seasonal storage problem. In the summer time when refinery stocks are being depleted and motor fuel prices are at their best the opposite conditions prevail for natural gasoline.

In many instances summer natural gasoline can profitably be stored in refinery tanks for winter consumption. Considerable use has already been made of this idea but the practice could become more widespread with mutual profit to both the refiner and natural gasoline manufacturer.

Possibly the most satisfactory solution to the seasonal storage problem is to install more storage facilities at natural gasoline plants. Butane-free natural gasoline can be stored through the hot summer months in inexpensive tanks. Near every natural gasoline plant there is no doubt an old crude oil storage tank which might be leased or purchased at a depreciated value. With cleaning and moderate repairs such tanks could be used to store many days' production of butane-free natural gasoline. Since most natural gasoline plants can extract excess butane in the winter time the stored low vapor-pressure natural gasoline could be brought up to such vapor pressure requirements as the winter market required.

The present storage facilities of the natural gasoline industry forces unwanted material on the customer in larger quantities than he can use in the summer time and creates a scarcity in the winter time, when the customer could use more than is available. Neither sales policy is sound. A rational program of natural gasoline manufacture and storage would include the summer manufacture and storage of butane-free natural gasoline permitting the buyer to establish the market in respect to volume and vapor pressure. As we all know, in the present practice the sales pressure of filled storage tanks now dictates the summer markets for natural gasoline.

## BUTANE CONTENT OF BLENDING NATURAL GASOLINE

The natural gasoline industry has never had quite enough courage to face the fact that there just isn't much market for butane in summer natural gasoline. The modern refinery, if it utilizes all the butanes-butenes formed in its cracking stills, can make a finished gasoline of 13-pound vapor pressure. Thus, into a market already crowded we are crowding still more butane.

If one assumes that butane-free natural gasoline merits a price corresponding to similar refinery products less the extra transportation, it can be calculated that butane in natural gasoline actually pulls

down the market value of the butane-free natural gasoline and this effect is very pronounced at summer price levels. This condition boils down to the fact that through the medium of price reductions the natural gasoline manufacturers are forcing their customer to buy something he does not need.

## RELATIVE QUALITY OF NATURAL GASOLINE

Perhaps the most urgent problem before the natural gasoline industry today is summarized by the following two facts:

(1) During the past decade there have been very pronounced improvements in the volatility and octane number of refinery gasoline.
(2) During the same interval there has been little improvement in the quality of natural gasoline.

This simply means that natural gasoline is worth relatively less as an ingredient of motor fuel than it was worth 10 years ago. The natural gasoline industry needs to give serious thought and action to this decreasing value of its product relative to refinery gasoline.

Recently we have made some interesting calculations pertaining to the trend in the volatility of refinery gasoline. According to these calculations five-sixths of the volatility of motor fuel in 1927 was obtained from natural gasoline, whereas in 1937, natural gasoline contributed only one fourth of the volatile fractions incorporated in motor fuel. Coincident with this change in the origin of the major supplies of volatile fractions, there has been a pronounced increase in the octane number of average refinery gasoline.

As a matter of fact with the inevitable reduction in vapor pressure of natural gasoline there has been a decline in the anti-knock value of natural gasoline. Thus, while refinery gasoline has been forging ahead, natural gasoline has slowly given ground.

Can anything be done to improve the quality and usefulness of natural gasoline? This is a serious question which should receive the courageous attention of natural gasoline manufacturers.

## VOLATILITY AS A PREMIUM MOTOR FUEL QUALITY

In a previous paper, the writer suggested that the natural gasoline industry should exploit volatility as the premium quality of motor fuel. It has always seemed that the oil industry missed a good thing when it did not emphasize volatility as thoroughly as anti-knock properties have been exploited. At these annual meetings we have had scientific proof that volatility can and does contribute in a major way to motor performance. Currently the market for premium motor fuel is in the doldrums. Maybe volatility is the best way to revive the market. Is it too late to do something about volatility as the premium quality of motor fuel?

## MAKING VOLATILITY MORE USEFUL

One of the chief difficulties in the marketing of natural gasoline is its limited usefulness in blending in summer grades of motor fuel. Early every fall the buyer's interest must be revived.

The pronounced differences in volatility of natural gasolines of high- and low-pentane content were carefully studied by the association in the development of the natural gasoline grading system. To provide for either intentional or unintentional variations in the pentane content of natural gasoline the specification factor defined by percentage evaporated at 140°F. was adopted as a major requirement.

The low-pentane naturals, i. e., those with very low percents evaporated at 140°F., are especially adapted for blending in summer motor fuels while the high-pentane naturals are ideal for blending in winter motor fuels.

As a means of overcoming the limited summer usefulness of natural gasoline it is suggested that renewed consideration be given to the removal of pentanes intended for blending in summer grades of motor fuel. The pentanes removed could be added to unprocessed natural gasoline going to storage for winter consumption. Or the removed pentanes could be stored separately in the event the practice permitted the sale of the entire output of the plant.

The summer grades of natural gasoline thus produced would fall in the lowest volatility grades of our grading system while the winter grades would fall in the highest. Not only would such a practice improve the seasonal usefulness of natural gasoline from a quality viewpoint but it would also greatly improve the seasonal quantity picture. And incidentally there would be a tendency toward a constant use of butane the year around.

Figure 1 shows what happened to the butane content, vapor pressure, and percent evaporated at 140° F. of one natural gasoline as the pentane content was regulated.

## MISCELLANEOUS WAYS OF IMPROVING USEFULNESS

Several important ways of improving the usefulness of natural gasoline which merit consideration are as follows:

(1) Bulk station blending of natural gasoline.
(2) Blending in crude oil for transportation to refineries.
(3) Transportation to refinery centers with poly feed.

## THE ANTI-KNOCK CHARACTERISTICS OF NATURAL GASOLINE

The octane numbers of the chief constituents of natural gasoline are shown in the following tabulation:

| | |
|---|---|
| Normal pentane | 65 |
| Iso-pentane | 90 |
| Normal butane | 91 |
| Iso-butane | 99 |

Unfortunately the hexanes and heavier of natural gasoline to not have very high octane numbers as is demonstrated by the following representative examples:

| Pentane Free Natural Gasoline | A.S.T.M. Octane Numbers | Reid Vapor Pressure |
|---|---|---|
| 1 | 60.2 | 4.45 |
| 2 | 66.2 | 3.30 |
| 3 | 57.0 | 3.60 |
| 4 | 63.9 | 3.15 |
| 5 | 56.4 | 4.05 |
| 6 | 61.0 | 4.50 |

The lowest-octane products in the above tabulation unfortunately represent the largest production while the highest octane samples were obtained from small plants operating in small oil pools. Thus the attack on the problem of improving the anti-knock qualities of natural gasoline can be concentrated on methods of improving the hexanes plus fraction which is usually about one third of the 26/70 volume.

It may become necessary for natural gasoline man-

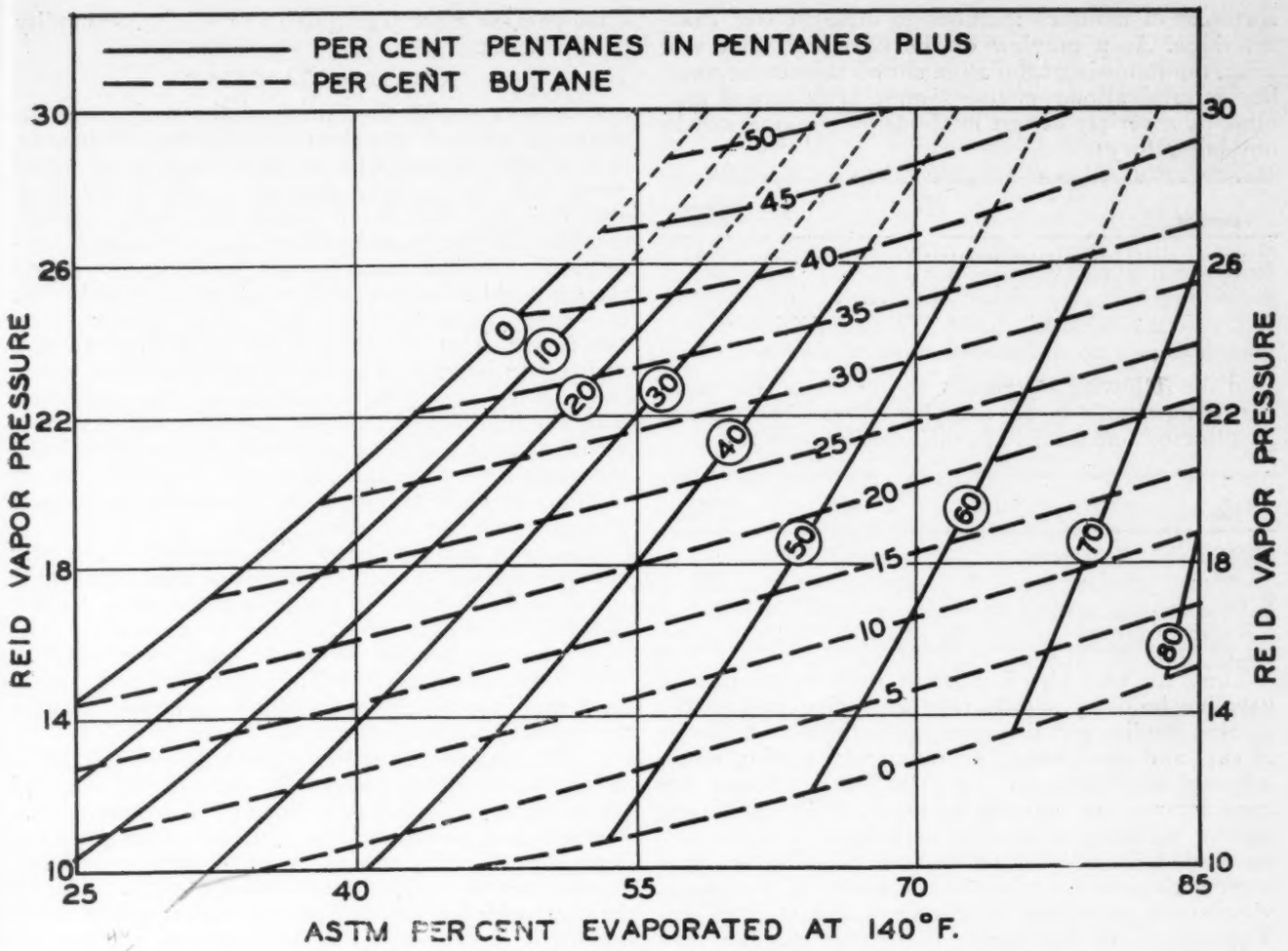



**FIGURE 1**

***The effect of control of pentane content on the volatility, vapor pressure and butane content of natural gasoline.***

ufacturers to apply refinery methods for upgrading the hexanes plus fraction of natural gasoline. Serious study should be given to the application of the various polymerization and reforming processes to this purpose.

The octane number loss caused by many sweetening processes can be greatly minimized by use of the copper sweeteners now going into such general use. To illustrate the magnitude of the possible losses the following example is cited for a plant handling a low vapor pressure natural gasoline:

| Natural Gasoline | OCTANE NUMBER | |
|---|---|---|
| | No TEL | 1 cc. TEL |
| Sour | 66.4 | 75.2 |
| Doctor sweetened | 64.7 | 73.0 |
| Copper sweetened | 66.4 | 75.0 |

It has been pointed out that sulfur content has a pronounced effect on lead response. Economic methods for sulfur removal will certainly improve the value of natural gasoline blended in ethylized motor fuels.

The superior lead response and the blending octane number effect of natural gasoline will go a long way toward curing the declining margin of anti-knock superiority over refinery gasoline. However, as the trend continues toward higher octane numbers, natural gasoline will lose relatively more and more unless ways are found to participate in the same trend.

## ANTI-KNOCK TESTING METHODS

For the past several years various organizations interested in gasoline and automobiles have been conducting road and laboratory tests to determine the knocking characteristics of cars and motor fuels. Many varieties of gasolines were used in the tests but natural gasoline was not among them. There were various poly gasolines, benzol blends, ethylized gasolines, straight-run gasolines, filling station gasolines, reference fuels, and various cracked gasolines but no natural gasoline.

Now it is a statistical fact that natural gasoline represents one twelfth of the nation's motor fuel supply. It is very important to the natural gasoline industry that the anti-knock behavior of natural gasoline be included in these studies that are used to establish commercial standards.

The existing standard knock testing methods are woefully inadequate for the testing of volatile gasolines. We have encountered vapor locking in our laboratory with ten pound motor fuels on hot summer days. It can be easily imagined what would happen to 20 pound natural gasoline.

Octane number has become a specification for export shipments of natural gasoline with a great as-

sortment of modified methods to measure this characteristic. As a preview of the confusion that will arise, the following tabulation shows the octane number determinations on one sample of 22-pound gasoline by a variety of test methods by one operator in one laboratory:

| Method | Octane Number |
|---|---|
| A | 74.1 |
| B | 76.1 |
| C | 72.2 |
| D | 74.2 |
| E | 73.0 |
| F | 74.3 |

And the following tabulation shows the octane number determinations on samples of another natural gasoline by one method in different laboratories:

| Laboratory | Octane Number |
|---|---|
| A | 75.6 |
| B | 73.0 |
| C | 76.4 |
| D | 77.1 |
| E | 76.3 |
| F | 75.1 |

Thus, for two very important reasons the natural gasoline industry should take an active part in the current studies pertaining to the anti-knock behavior of cars and gasolines. (1) Commercial testing methods and standards may be established without due consideration of natural gasoline. (2) Anti-knock testing methods applicable to natural gasoline will be needed. Two lesser reasons are (3) Contact with such work provides valuable knowledge of trends and viewpoints pertaining to gasolines and engines. (4) The specialized knowledge of natural gasoline men can be helpful to the other workers.

The Natural Gasoline Association of America could very well afford to designate some capable, independent laboratory to represent it in this important work.

## ISO-PENTANE

In a recent article we have called attention to the fact that iso-pentane is an ideal blending agent in the manufacture of 100-octane number aviation gasoline. As a matter of fact, Phillips Petroleum Company has marketed millions of gallons of "iso-pentanized" aviation natural gasoline. The process of manufacture consists of separating the natural gasoline into butanes and lighter, pentanes and pentane-free natural gasoline. The iso and normal pentanes are separated and the iso-pentane blended with the pentane-free natural to the conventional seven-pound vapor pressure specification.

Iso-pentane, with its comparatively low vapor pressure of 20 pounds and exceptionally high octane number of 90, combined with its outstanding susceptibility to lead, would be an ideal stock in many other difficult blending problems.

The removal of iso-pentane from natural gasoline would, of course, lower the quality of the residual natural gasoline to a slight extent. For equal vapor pressure products the additional butane that could be incorporated would offset the loss to some extent.

However, the essential fact is that the superior qualities of iso-pentane are largely lost among the relatively inferior other ingredients of natural gasoline. There is the distinct possibility that the natural gasoline industry and its customers would both profit if iso-pentane were segregated as distinct commodity of commerce.

## AVIATION GASOLINE

It is noteworthy that three of the major constituents of natural gasoline, iso-pentane, iso-butane, and normal butane, with modest additions of tetraethyl lead, have octane numbers much in excess of 100. Is it too difficult an engineering feat to design airplane fuel tanks and systems to handle these materials? Aviation interests are working on supercharged cabins for stratosphere flying. Certainly that is a much more difficult engineering problem than the fuel system problem. Here is an ideal market waiting to be tapped. It is a quality market where the quality is worth something to the customer. The distribution of aviation gasoline will probably never present the same problems as motor fuel distribution since although there may be a dozen filling stations at each airport there cannot be an airport at each street intersection.

You may think this is a pipe dream but the only reason butane and pentane cannot be used as aviation gasoline is because it has not been done before. Admiral Byrd considered the use of propane as aviation gasoline for his Antarctic expedition until he found that at minus 100°F. it took almost as much heat and just as much trouble to vaporize propane as ordinary aviation gasoline.

In the meantime the literature is full of references to processes which convert iso-butane, butane, and their refinery cousins, to extremely high octane number aviation gasoline. One process (alkylation) has been described by means of which ethane and iso-butane can be converted to neohexane (2-2 dimethyl butane) which has 97 or better octane number. Other synthetic hydrocarbons of high octane number are possible.

It may thus be said with some assurance that when better aviation gasolines are made the natural gasoline industry will make them.

## POLYMERIZATION

We have all heard of the attempts made in Germany, France and Italy to operate automobiles on gas derived from charcoal, coke oven gas, and other fuel gases. Natural gas would be an ideal automotive fuel. One hundred cubic feet of natural gas would propel an automobile as far as would a gallon of gasoline. Thus at the prevailing retail prices (taxes included) a dollar's worth of natural gas would propel an automobile five times as far as a dollar's worth of gasoline.

Unfortunately, the form-utility of natural gas is very adverse to its use as an automotive fuel. Thus, if natural gas were compressed to a pressure of 3000 pounds per square inch the gas tank would have to be about four times as large as the present gasoline tank to hold as many Btu's.

The polymerization processes change the energy available in natural gas from the gaseous to the liquid form and thus create new markets for natural gas. The extreme economic importance of such a transformation is exemplified by the manufacture of 100 octane aviation gasoline with butane as the raw material. Butane is almost but not quite a liquid. Its octane number is in excess of the requirements for 100 octane number motor fuel. Thus, the only essential change that is effected by the expensive processing required to make iso-octane is to change the boil-

ing point from 27 to 206°F. Basically, the polymerization process merely converts gaseous energy to the liquid form.

One way of dramatizing the economic significance of the polymerization processes is to calculate the amount of motor fuel that could be made from the individual hydrocarbons of natural gas if they could be converted quantitatively to gasoline. The "if" in the preceding sentence is a very big one. For example, the conversion of methane to liquid products has not progressed nearly so far as the conversion of ethane, propane, and butane. Another big problem is the extraction of the various hydrocarbons as poly feed. The economic size of plants is another vital problem. However, the following tabulation shows the quantity of motor fuel that would be obtained from one million cubic feet of average natural gas if all the hydrocarbons could be converted quantitatively into motor fuel and making no provisions for fuel requirements.

| | |
|---|---|
| Methane | 4,900 gallons motor fuel |
| Ethane | 1,260 gallons motor fuel |
| Propane | 1,050 gallons motor fuel |
| Butane | 590 gallons motor fuel |
| Pentanes plus | 800 gallons natural gasoline |
| Total | 8,600 gallons |

Polymerization processes have been described in the literature which can convert ethane, propane, and butane with weight yields ranging from 10 to almost 100 percent. With the high-yield processes natural gas can be made to produce four times as much gasoline as is now obtained. The product would be a finished motor fuel of high octane number, low vapor pressure, and suitable volatility.

Of course, it will take many years to perfect and apply the polymerization processes to their fullest economic advantage. There are innumerable problems of chemical, engineering, economic, legal, and financial nature to be solved. Thus, it may be stated that the preceding calculations represent an objective which can never be fully attained.

If it should develop that the application of these gas conversion processes will ultimately enhance the value of natural gas it is conceivable that the oil industry will begin hunting for natural gas everywhere as thoroughly as has been done in West Virginia, where for every pound of crude oil produced there are also produced 5.2 pounds of natural gas. Elsewhere the ratio is about 0.4 pound of natural gas per pound of crude oil.

Thus, the polymerization processes may ultimately revolutionize the entire oil industry. Certainly the situation challenges the imagination, initiative, and industry of natural gasoline manufacturers to assure that this development progresses as rapidly, as soundly, and as surely as possible.

## CHEMICAL POSSIBILITIES

As is exemplified by the polymerization processes, the classic definition of paraffin as meaning "little affinity" has ceased to worry the chemists. Chemists everywhere are turning their attention to petroleum as a raw material for new and better and cheaper chemicals. Several large oil companies have entered the chemical manufacturing field. For example, the manufacture of iso-octane is an out and out chemical process where it is noteworthy that those companies who were already in the chemical field have thus far made the most rapid progress. One of the country's largest chemical companies manufactures innumerable synthetic organic chemicals from hydrocarbon raw materials. Incidentally, in 1937, that concern invested over fifteen million dollars on construction work in its chemical division and cited as the first item of its 1937 construction program "Installation of pipe lines to, and the erection of raw material processing equipment at chemical plants."

The refinements of the polymerization processes such as alkylation, dehydrogenation, isomerization, and selective polymerization open new fields of synthesis to the chemical industry which coupled with the other steps of synthetic chemical manufacture will lead to many new products.

In a recent issue of Life there appeared a picture of German tires made from Buna rubber. In Germany the raw materials for this synthetic rubber are coal and limestone, which are processed to yield butadiene which in turn is polymerized to make the synthetic rubber. Butadiene is the doubly unsaturated hydrocarbon corresponding to normal butane.

As another example of the chemical possibilities of the light hydrocarbons, we have recently described a series of resins made from olefins and sulfur dioxide. Other companies are giving serious attention to hydrocarbons as the basis for new plastics manufacture.

As a general rule, the more nearly pure the hydrocarbon raw material the more economic will be the chemical manufacturing process. Thus, the natural gasoline industry with its great skill in the extraction and separation of the lighter hydrocarbons, with its large raw material resources, and with cheap fuel is in an excellent position to serve the chemical industry.

## DIRECT FUEL POSSIBILITIES

The use of liquefied petroleum gas, or natural gasoline, as a direct motor fuel has received much attention. Considerable progress has been made with automotive equipment and with stationary equipment. There are many conflicting economic aspects of this development which require careful study. However, here is another market for light ends which should be intelligently cultivated.

## PRORATION

Proration and the growing practice of unitization have introduced new problems for the natural gasoline manufacturer. The scientific study of reservoir fluids and formations is bringing about an entirely new concept of natural gasoline production. Such developments as crude oil rectification, maximum gas/oil ratios, spacing regulations, distillate production, and many others require, more than ever before, the utmost cooperation between the oil producer and the natural gasoline manufacturer. A striking example of such cooperation in practice is found in East Texas where the oil producers take their oil on a schedule designed to cause a steady field gas production for the benefit of the natural gasoline plants.

## CONCLUSION

In these few paragraphs it has been possible to mention but briefly a few of the problems and possibilities of the natural gasoline industry. There are many others and much more could be said about the ones mentioned. Nevertheless, enough has been said to demonstrate that imagination is very much alive. There are far more achievements ahead of than behind the natural gasoline industry.

# How Mid-Continents' New Employees Learn About Accident Prevention

THE safety work in the Mid-Continent Petroleum Corporation is headed by F. B. Koontz, vice president in charge of manufacture and his assistant, D. Glenn Morgan, general refinery superintendent, with the safety department directed by Elmo D. Murphey, safety engineer, who has been active in this position for 17 years. Departmental heads in the refinery, as well as in the field and distribution divisions are closely joined in the system, with each employee participating individually in the program.

To impress upon the new employee the importance of avoiding injury while at work, and when off duty too, for that matter, he is directed to the safety department office immediately after passing the required physical examination. In this office, Safety Engineer Murphey discusses with the man what safety means, pointing out to him the gravity of neglecting common hazards, and impressing upon him the urgent need of continual vigilance. Excerpts from these remarks follow:

"Before you go to work in our refinery, I would like to talk a little while with you on the subject of safety. When you become an employee of this refinery, you assume two duties or obligations toward safety in connection with your regular work. The first is to be constantly on the lookout for danger. This does not mean that your work here is necessarily more dangerous than in any other manufacturing institution, but you must be impressed with the fact that wherever you go, and whatever you do, you are bound to meet a certain amount of danger. The machinery and the processes operated, and the products that are manufactured can be safely handled, or they

***A daily safety meeting underway. Such meetings may be a minute long, or five to ten minutes and they are held throughout every department for all shifts.***

can become dangerous if not used and handled correctly. Therefore, you must be constantly on the alert for dangerous conditions, or any sign of danger.

"The second duty that you and all other employees of the Mid-Continent Petroleum Corporation have toward safety in connection with your regular work is to report immediately or correct at once, any dangerous condition or practice which comes to your attention.

"You will notice that I said you should either report or correct immediately. What do I mean by the distinction between the two? I mean that an employee can often correct an unsafe condition or practice in a few moments and see that it is made safe without the formality of hunting up someone else to have it done. Take for an example a board full of nails. If you see such a board laying around where someone might step on the points sticking up, the board can be placed out of a dangerous position without loss of much time. Broken bottles are treated in the same manner, or any other condition which may present a hazard, which in your judgement can be corrected without assistance from another employee.

### THINGS TO REPORT

"Reporting unsafe conditions means that when you see a ladder that is broken, a leaking pipe line, or machinery out of repair, you should, and are required to report the condition immediately to your superior who will issue an order for immediate repairs. Such conditions will perhaps be out of your line of work, and you may not be in the maintenance department, but by reporting the condition, you may remove a hazard that might cause an injury, and at the same time prevent property damage.

"Further, I want to explain our use of the terms, 'accident,' 'accidental injury' and 'personal injuries.' Take the word 'accident.' Most of us confuse this with an occurrence which causes us to become hurt. A so-called accident may be the cause of an injury, and again it may not. We may escape an injury by a few seconds or a few inches and still have a very serious accident. The word 'accident' is misused nearly every day by all of us. When we consult a dictionary for the first time, we are surprised to find that the word accident is an occurrence which is unforeseen, unexpected, not anticipated, and without apparent cause. You notice this definition does not say without any cause, but it does say without apparent cause.

"If a man is using a hammer and chipping chisel to cut a key-way, or works on metal without using goggles provided for just such a purpose, and a sliver of steel flies into his eyes, it is often spoken of as an accident. Was not the cause of his injury perfectly apparent because of his failure to use protective devices for his eyes? We may read the headlines in the morning paper about a bad accident four miles south of town when a driver of an automobile attempting to negotiate a curve on an icy highway lost control of his car, ran into the ditch and killed himself and passenger. Under the definition of the word accident this was not an accident at all. The cause was perfectly apparent. In other words, the driver was attempting to drive too fast around an icy curve and the laws of nature could not be overcome.

"Taking for granted that you are a most careful driver, can you guarantee me that when you go out on the highway with your car, no matter how careful you may be, you are practicing safety first 100 percent of the time? Is it not true that you must share the highway with someone who may be a drunken fool, may be subject to a sudden fit of epilepsy, have poor eyesight or unable to read roadside signs?

### WHAT IS AN ACCIDENT

"'Well,' you say, 'What is a real accident like?' I think one like this illustration might be classed as an accident. If I buy a new car and have taken good care of it the few days that I have owned it, drive out on the highway tomorrow morning perfectly sober and in control of my faculties, on a good stretch of pavement with a sensible speed, when suddenly the tie-rod of my steering gear breaks. I lose control of the vehicle as it leaves the road and turns over several times. I may not be killed, but I have suffered a broken arm and numerous body scratches. Then I firmly believe that I have had a true accident; something that happened without apparent cause.

"Too many of us use the term 'accident' or 'accidental injury' as an alibi for our mistakes and negligence, lack of judgment, or just taking a chance that we will not be injured if we do not use common sense precautions, and utilize the safety tools that the company has provided for such work as we may be doing. If a man is injured in this manner, he has not had an 'accident' at all. If we get the underlying truth be-

***Elmo D. Murphy, Safety Engineer, Mid-Continent Petroleum Corporation, West Tulsa refinery, Oklahoma.***

***Cutting machine with welder watching it cut into a thick sheet of steel. The welder is wearing safety goggles equipped with dark lenses for protection against the dangerous ultra-violet rays at close range.***

hind the definition of the word accident, that is 'without any apparent cause,' we will all become more safety-minded, real safety-performing people.

### WHO ARE INTERESTED IN SAFETY?

"Who has the responsibility for the prevention of injuries to employees in this refinery? As I see it, three different groups are vitally interested in the prevention of injuries. First, the management. They are interested for two different reasons: first, injuries cost money and money spent to repair injuries is money gone to waste, for no group or individual realizes a profit out of any injury. Another reason they are interested in the prevention of injuries is because the officers of this company are just like you and I. They are men who have hearts in their chests and they do not want to see any person get hurt, crippled, killed or laid off because of some occurrence that might have been prevented.

"Another group just under the top management that has an interest in your welfare and a responsibility for the prevention of accidents, and that group is composed of supervisors and foremen. It is their job to get the work done, but to get it done safely and at the lowest cost. They realize that if injuries are suffered by their men they affect the cost of the products which are manufactured in their departments. Not only is this the reason for their concern and responsibility, but they have a deep interest in the safety and welfare of the employees under their direction.

"The third, and perhaps the most important group that has an interest and a responsibility for the prevention of injuries is that group made up of the refinery employees as a whole, the workers themselves, and their families. This group has the most to gain or lose in safety work, and they, of all three groups can least afford the money loss that is the inevitable part of lost-time injuries. As workers, how many of us have a reserve fund, or back-log to fall back upon if we are disabled and are forced to lose time from our work? When we come to think of it, and give the subject thoughtful consideration, it is not strange that any company should be compelled to urge, cajole and worry with its workers to follow safety practices? The workers having the most to gain or lose should always be the most staunch supporters of a safety program, and should insist that safety practice be followed.

### ALL SAFETY MEN

"In starting to work today, you become one of the safety men of this refinery. You may be hired as a laborer, a boiler-maker, or as an operator of a still, but you are to become one of our safety men. We know you will be glad that you are to work with a good, safe bunch of men in the plant. We want you to be the same kind.

"In the refinery we have what we call 'Daily Safety Observers' in every department. The foremen of each department makes out a list of daily safety observers at the beginning of each month. One man of the group in the department serves as safety observer each day and has this responsibility in addition to his regular duties. He is on the lookout constantly during this time for any kind of unsafe conditions or practices, whether it originates with equipment or the men themselves. In addition to being constantly on the alert while he is working at his regular duties, he takes ten minutes of his time to look over the entire department some time during the day. He inspects the machines, the equipment being used, or that which is idle, the tools, the material and observes what kind of housekeeping is being conducted by his fellow employees. Any irregularity or any unsafe machine or practices is reported immediately to his foreman, and a list made out for permanent filing of what he has discovered.

"There is also in each department a permanent man who serves every day of the month and perhaps for months at a time who is called a 'Department Safety Representative.' At any time you have safety matters to discuss, or any questions you wish to ask on safety problems, consult your foreman, assistant foreman or the 'departmental safety representative.' These representatives will listen to your questions, take any report you wish to make on unsafe working

*A demonstration of the proper manner to get into rescue apparatus. This is a self-contained oxygen bottle used for going into dangerous atmospheres.*

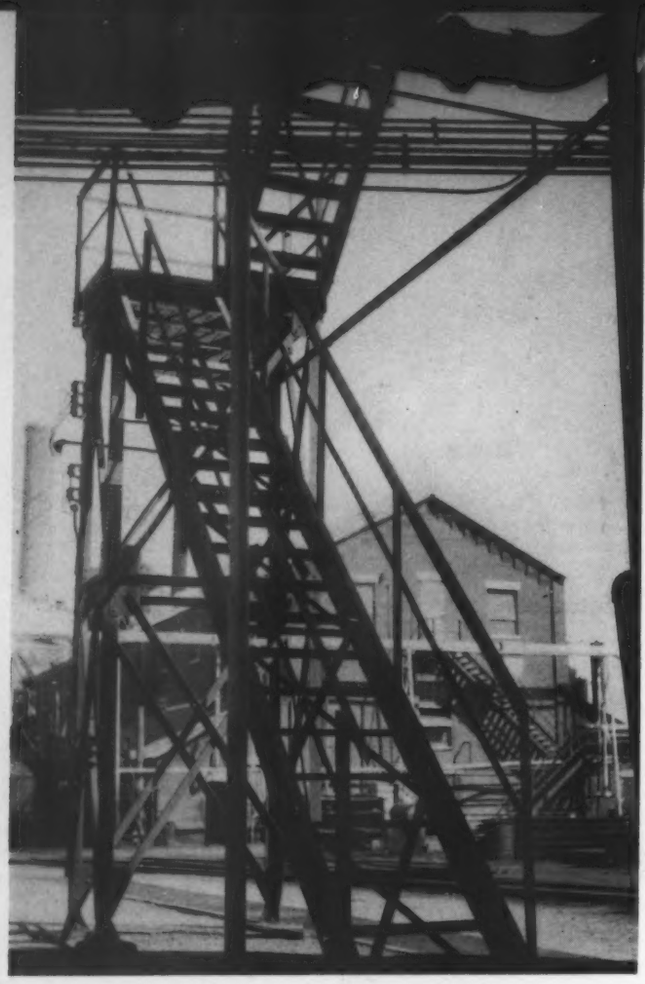
conditions, and pass them on for consideration, approval, or will immediately repair equipment or halt any unsafe practice. These departmental safety representatives have a separate organization and use an office assigned to them, and meet at least once each month as a group.

"Another way that we have of keeping safety alive in every department is to conduct daily safety meetings in every department, and the night shifts that go on at midnight also have these daily meetings. These meetings may be only one minute in length, five minutes or ten, or perhaps longer as the case may be. Each employee is given an opportunity to speak in these meetings and to present his ideas about how the plant or department may be made a safer place in which to work. We hope that you will take active part in these meetings, get some real help from the discussions, and that you will become an even better safety man in the future than you are at present.

## PHYSICAL PRECAUTIONS

"For your protection and safety the company furnishes all kinds of safety equipment. We have in use throughout the plant steel walkways and ladders on all permanent structures. We have guard-rails to prevent you from falling from high places. We have

*Tank cleaners at Mid-Continent Petroleum Corporation's West Tulsa refinery wearing various types of equipment such as air hose masks, cannister gas masks and respirators.*



*Modern steel stairway with open-work steps, double hand rails and toe boards.*

emergency guy wires that have escapes on them so you may descend from high places quickly in case of an emergency. We provide gas masks to protect you from dangerous atmospheres, and respirators for protection against dust and chemicals of various kinds, as well as when you are engaged in painting.

"We provide the very best and safest types of goggles for the protection of your eyes from impact of flying bits of metal, gravel or other objects from the air, and goggles with dark lenses for protection against dangerous welding rays. There are rubber gloves for you to wear when you handle acids or caustic, and rubber boots for the same condition. We have slicker suits and hats, and recommend and can provide safety shoes and boots with steel toecaps to protect your feet from being bruised or broken when heavy objects may be dropped.

### EMERGENCY AID

"We have trained first-aid men who can take care of emergency treatment and rescue apparatus such as half-hour breathing machines, oxygen kits and various kinds of masks. We give training in first-aid at various times so you can offer assistance to fellow workers, and we have in our medical department a first-aid man on duty at all times to take care of any injury you may sustain. Never neglect the slightest scratch or small injury, but report immediately to the first-aid department where it can have proper attention.

"I am now going to give you one of our rule books. The importance of cooperation and team work is stressed. The importance of wearing safe shoes, particularly ones with soles in good condition. The importance of keeping a job pepped up and cleaned up with good housekeeping in the department in which you work is emphasized. You are told not to guess at anything, but always know before you go into a job. You are told of the dangers of unnecessary haste—the kind of haste that makes waste, and may result in injury to yourself and fellow workers. You are told of the importance of self-control, the control of the temper and the elimination of horse-play or circus stunts. You are told of the dangers of fire and explosion, and how to avoid them. In this rule book, you are told of the importance of maintaining your health and obtaining the proper amount of rest and sleep so that you will be wide-a-wake on the job. You are told of rules governing riding on company trucks and automobiles, such as not to get on or off while the vehicle is in motion; not to ride with any part of your body hanging over the sides or rear end, and not to have more than one man with the driver in the front seat, and not to ride on running boards, fenders or bumpers.

"The safety slogan, or motto of the Mid-Continent Petroleum Corporation for the past five years has been, 'Use your head.' The slogan we are emphasizing in 1938 is, 'Every man a safety man.' You are asked to take this book and read it carefully within the next 24 hours and return the receipt showing that you have read it and that you will follow it to the best of your ability. I hope you will become a real safety man in working with our company, and that you will follow our old safety motto of 'use your head' and that you will take up the idea back of our new slogan 'every man a safety man.'"

*Safety walkway along the side of the treating columns, with safety tread and double hand rails.*

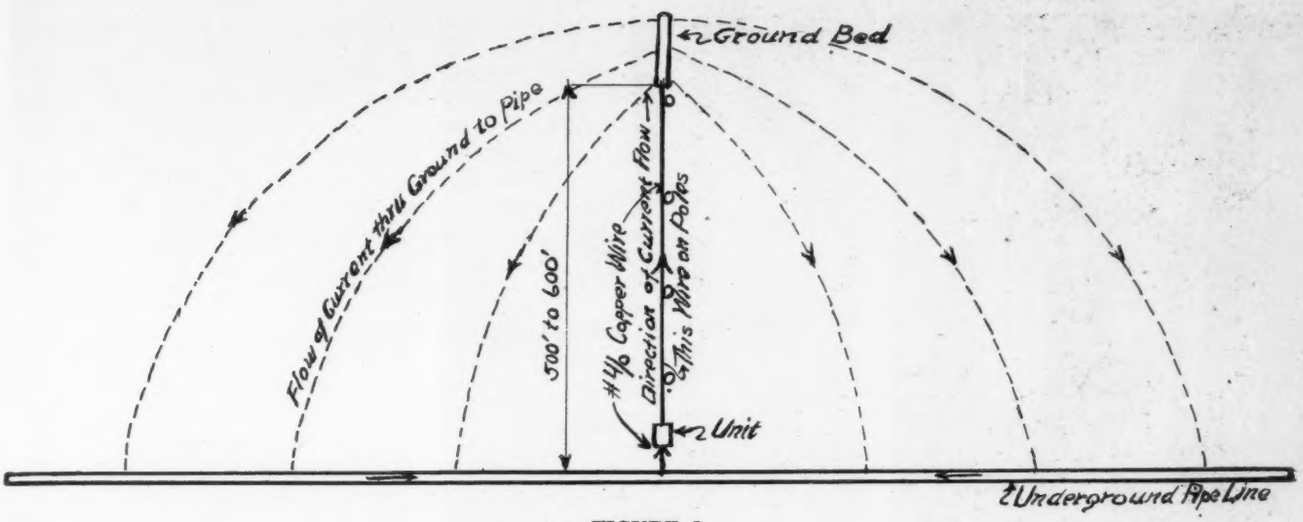



**FIGURE 1**
***Diagrammatic plan of cathodic protection unit.***

# Cathodic Protection

## *Its Application in Refineries*

DENIS S. SNEIGR

**CATHODIC protection of metals against soil corrosion or electrolysis, first used in the protection of natural gas transmission lines, within the past few years has been found applicable to a number of other phases of the petroleum industry. It has been found worthwhile in the protection of pump shafts, some refineries experiencing corrosion trouble at their water wells have applied the system with marked success. Refinery and other tank farms use it for protection of the large tank bottoms, and its use has extended to all types of pipe lines for carrying oil, natural gas, refinery gas, water and so forth. The accompanying discussion reviews the development of cathodic protection and describes the various types of equipments and systems available and now in wide usage.**

CATHODIC protection is applicable to practically any piece of metal which is in contact with a corrosive soil. However, more factors enter into the question than simply applying a cathodic protection system to the metal. The composition of the soil as well as the composition of the particular piece of metal and several other factors all have a bearing on the situation.

Soil corrosion is an electro-chemical action which occurs when chemical conditions in the soil surrounding a piece of metal generate electrical currents that are attracted by the piece of metal. Thus the potential of the piece of metal is increased until it surpasses the potential of the surrounding soil. Then at the point or points of greatest conductivity, these currents leave the piece of metal. And it is at these points that corrosion occurs.

The principle of cathodic protection is to prevent the electrical currents from leaving the piece of metal except at certain desired points. As an example, the cathodic protection of a section of pipe line is described:

A ground bed is installed at some distance from the pipe line. To this ground bed the positive terminal of a source of electrical energy is connected, while the negative terminal is attached to the pipe line. In operation the electrical current enters the earth at the ground bed and returns through the intervening soil to the pipe line. In this manner the potential of the earth around the pipe line is maintained at a higher level than the potential of the pipe line. Figure 1 illustrates the principle of cathodic protection of a pipe line.

### TYPE OF UNITS

In general use today there are four types of cathodic protection units. These are: The motor generator set, the rectifying set, the wind driven unit, and the gas-engine unit.

The motor generator set and the rectifying set are employed wherever commercial power lines are available. The motor generator set consists simply of a

**FIGURE 2**
***Early rectifying units were assembled in small houses.***

**FIGURE 3**
***Late type of rectifying units are simplified and the set is enclosed in a metal box and mounted on a pole.***

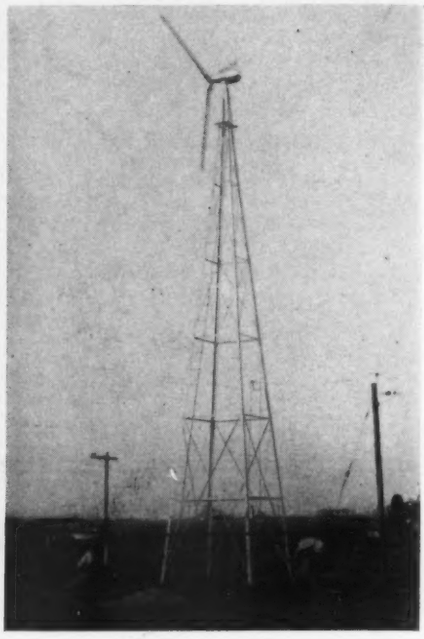


**FIGURE 4**
***Improved type of wind driven unit for cathodic protection of piping.***

generator driven by an electric motor. Such sets can be built to discharge any required amount of current and are being installed mainly in tank farms, pump stations and refinery yards. The motor generator set requires little or no attention.

The rectifying unit consists of a transformer for changing the high voltage of a power line to the required low voltage and a rectifying unit. This unit is made up of multiple 3-ampere units which convert the alternating current to the direct current necessary for cathodic protection. The number of 3-ampere units used is dependent upon the particular installation. For example, if 30 amperes were required 10 3-ampere units would be employed.

Such units have been and are being installed wherever a pipe line is conveniently located with respect to a power line. Since there are no moving parts in the unit, these sets require practically no attention once they are installed. The first sets of this type were assembled in small houses constructed for the purpose, as shown in Figure 2. However, since then the unit has been simplified, and now the entire set is enclosed in a metal box and mounted on a pole, as shown in Figure 3. It is estimated that the average life of the rectifying unit is about 10 years and there are a great number of these sets in service today.

The wind-driven unit—first used in 1935—consists of a windmill which operates a generator. When this machine first was placed in commercial operation it consisted of a two-bladed propeller, a generator, and a tail to keep the machine headed into the wind. Since then, however, numerous improvements and refinements have been made. Figure 4 shows a late model wind-driven unit.

The latest type wind-driven generator consists of a three-bladed, variable-pitch propeller and a generator. The tail has been eliminated and the propeller mounted at the rear of the machine where it serves both as a propeller and as a tail. The elimination of the tail reduced vibration and weight.

The addition of the third blade to the propeller also increased the adaptibility of the machine to varying wind conditions in widely separated sections of the country. For about a year after its introduction, the use of the wind-driven generator was confined mainly to Texas. However, its utilization rapidly expanded to other parts of the continent, including New Mexico, Kansas, Montana, Oklahoma, Arizona, Utah, Louisiana and Mexico.

The new wind-driven unit operates on a direct drive between the propeller and the generator, replacing the step-up gear found on the earlier models.

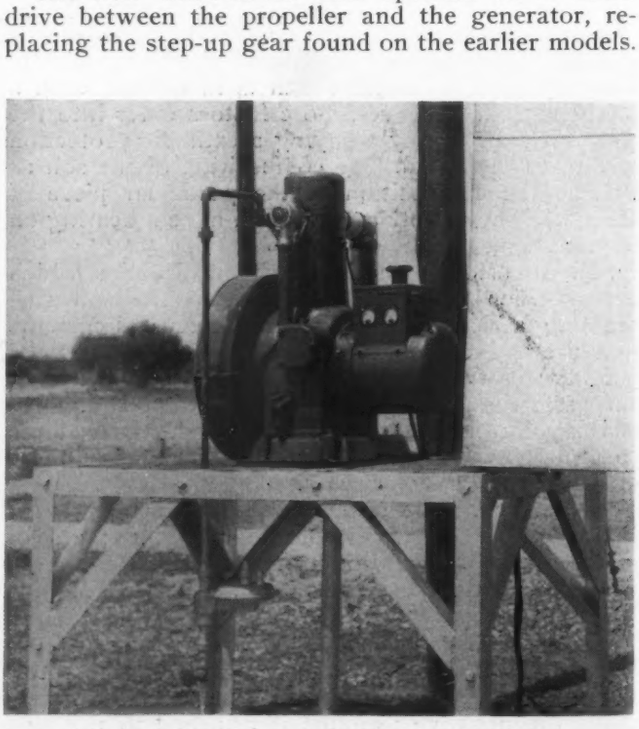


**FIGURE 5**
***The engine unit consists of an internal combustion engine burning either natural gas, gasoline or kerosene, the engine driving the generator. The unit above is open for inspection.***

With the direct drive a slower speed generator is used which operates between 52 and 240 r.p.m., at the latter speed the maximum output being reached.

The generators on the wind-driven unit are available in two sizes—12-volts and 40-amperes and 20-volts and 80-amperes. Two other improvements on the latest machine are the thermal element which protects the generator against shorts, open circuits, and over-loads and the manually operated friction brake which is used to stop the machine for inspection.

The gas-engine unit is an internal-combustion engine burning either natural gas, gasoline or kerosene, which drives a generator. Figures 5 and 6 show a gas-engine unit opened for inspection and closed as it is during operation. The earlier models of these engines had a single cylinder and were started with a battery which was then cut out and power from the generator used in the ignition system. The later models have two cylinders while a magneto has been substituted to supply the power formerly derived from the generator.

The early models were controlled by a governor; however, on the newer engines the torque control principle has replaced the governor. The torque control principle operates the engine at varying speeds depending upon the load. These engines operate between 400 and 900 r.p.m. and when a speed of 1200 r.p.m. is reached, due either to a greatly decreased or a greatly increased load, an automatic over-speed device shuts down the engine.

Both the wind-driven unit and the engine-driven unit are used widely in districts remote from power lines where they provide an economical source of electrical energy. The windmill can be mounted on towers of varying heights to overcome local obstructions. In South Louisiana, where minor floods are a frequent occurrence, the gas engines are mounted on towers to escape the waters. Figure 7 shows a gas engine mounted in such a manner.

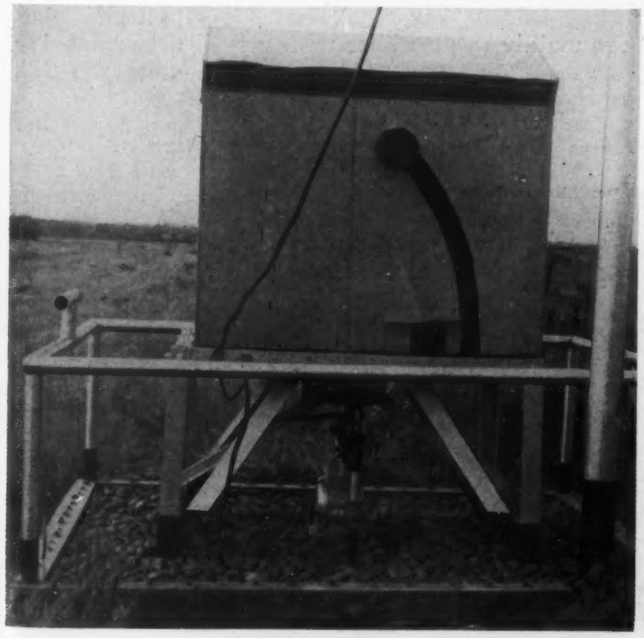


**FIGURE 6**

***Showing the manner in which the engine driven generator unit is protected with a small metal housing while in service.***

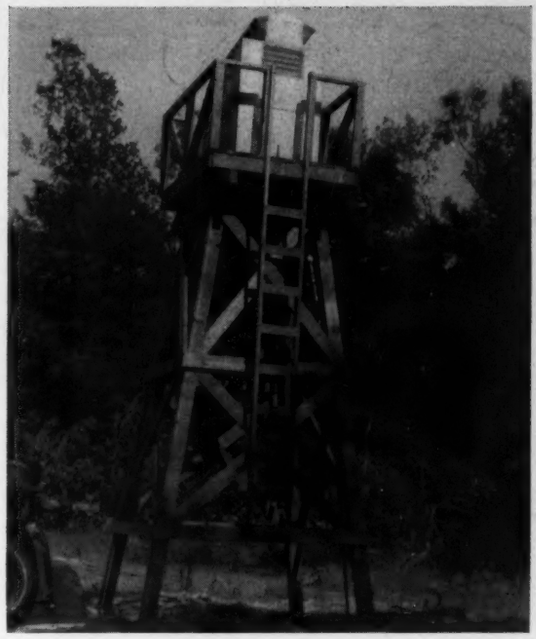


**FIGURE 7**

***Gas engine driven units for cathodic protection mounted on tower in region where minor floods are frequent.***

Starr Thayer, one of the foremost authorities on cathodic protection, was instrumental in bringing about the first practical application of this method of protecting pipe lines from electrolytic corrosion. Before then, Thayer as well as other investigators in this field had been conducting laboratory experiments along these lines.

However, in 1932, Thayer brought his equipment out of the laboratory stage and applied it to an actual field test on a six-inch pipe line four miles long, near Sugarland, Texas. Here the test proved that corrosion could be arrested completely and at reasonable cost.

The next installation was on the United Gas line between New Orleans and Baton Rouge, Louisiana. This line was laid in 1927 and by the summer of 1932, about 5 miles of this line had corroded to the extent that a reconditioning program was considered necessary. But due to the success of the field test near Sugarland, the reconditioning program was postponed and cathodic protection applied to the line.

The success of these first installations has led, within the past few years, to a widespread application of cathodic protection not only to pipe lines of all kinds but to other pieces of equipment liable to corrosion. For example, at a refinery in South Louisiana, several water wells were abandoned as a result of excessive corrosion. Cathodic protection was applied to the wells and the corrosion halted. These wells are shallow, operated by electric pumps and it was a simple matter to connect rectifying units and afford the wells protection.

The Texas Pipe Line Company, which was instrumental in the development of the wind-driven generator, evolved a method of protecting storage tank bottoms from corrosion. A tank farm, with large quantities of metal in direct contact with the earth, tends to attract electrical currents since this metallic area acts as a ground to the pipe lines entering the tank farm. In leaving the tank bottoms, these currents act upon the steel tank bottoms in the same

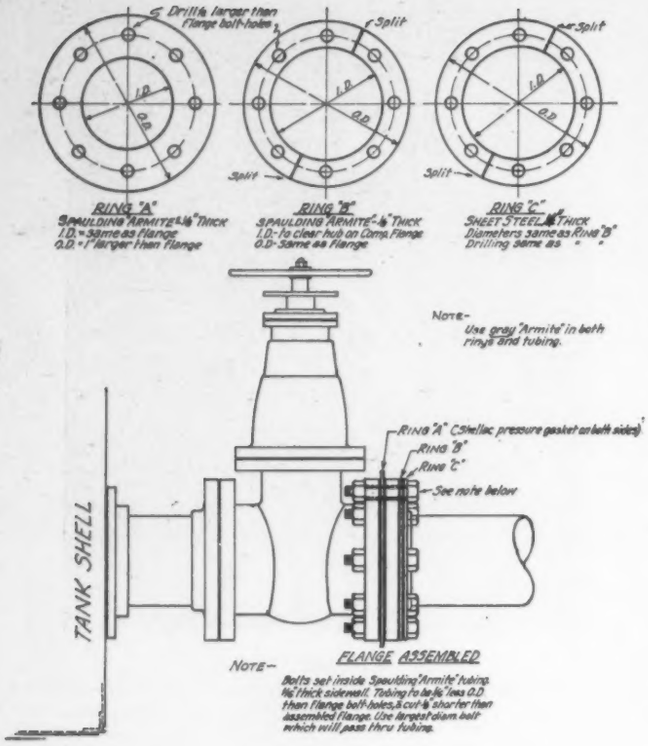

Drill ⅛ larger than flange bolt-holes
Split
RING "A"
Spaulding "Armite" ⅛" Thick
I.D. = Same as Flange
O.D. = 1" larger than Flange
RING "B"
Spaulding "Armite" ⅛" Thick
I.D. = to clear Hub on Comp. Flange
O.D. = Same as Flange
RING "C"
Sheet Steel ⅛" Thick
Diameters same as Ring "B"
Drilling same as " "
Note- Use gray "Armite" in both rings and tubing.
RING "A" (Shellac pressure gasket on both sides)
RING "B"
RING "C"
See note below
TANK SHELL
Note-
FLANGE ASSEMBLED
Bolts set inside Spaulding "Armite" tubing. ⅛" thick sidewall. Tubing to be ⅛" less O.D. than flange bolt-holes, & cut ⅛" shorter than assembled flange. Use largest diam. bolt which will pass thru tubing.

**FIGURE 8**
***Detail of insulating flange for storage tank gate valves.***

manner that they would upon an unprotected pipe line. At the points where the currents leave the bottom, corrosion occurs. Most of these electrical currents enter the tanks over the pipe lines and as a means of stopping this corrosion, The Texas Pipe Line Company has installed insulators at the gate valves leading to each tank.

The insulator consists of three ring gaskets each ⅛-inch thick. These gaskets are installed at the gate valve connection. Two of these rings are composed of a high dielectric fiber and the third ring is of sheet steel. These rings have the necessary holes for the bolts which hold the flange assembly together. In order to complete the insulation, the bolts are encased in tubes of the same dielectric material as the insulating ring gaskets. The three ring gaskets and the bolts are assembled as shown in Figure 8.

In order to stop some of the current flow, the line which leads from the main transmission line to the tank farm is raised horizontally above the ground for a distance of 75 feet to 150 feet. In this elevated section, an insulated flange union is installed. The elevation of the pipe and the insulated flange union tend to retard the flow of electrical current.

The Texas Pipe Line Company first installed these insulating units at the Electra tank farm. Since then similar units have been installed at almost every tank farm of the company's system. Tests made since these insulators were installed on the tanks show that no appreciable amount of current is flowing from the tanks to the earth.

## GROUND BEDS

When applying cathodic protection to a pipe line, either of two types of ground beds are used—the vertical or the horizontal. However, the vertical ground bed presents the greater advantages and is in more general use. A vertical ground bed is constructed by sinking a number of vertical pipes in the earth and then bonding the tops of the pipes together.

The usual method for constructing a vertical ground bed is to use a core drilling rig with large diameter bits. Some engineers permit the tops of the vertical pipes to show above the ground level while others sink the pipes so that the tops will be at least two feet below ground level. After the pipes are set in the holes, drilling mud usually is poured in to fill all the space both inside and outside the pipes.

The horizontal ground bed consists of a continuous length of pipe laid in a trench about six feet deep. Great care usually is taken in choosing the site of a ground bed, test holes being drilled and resistance measurements of soil samples being made. For a ground bed, engineers usually select the spot where the soil shows the lowest resistance. An exception to this is the case of a sandy soil and a clay, better results being obtained from a clay than from a sand even if the sand shows a lower resistance.

Cathodic protection—as far as its application is concerned—may be said to be still restricted, even within the oil industry. So far, its application has been mainly to pipe lines with very little work being done from any other angle. However, it appears that the future will see many and varied applications in the refineries and gasoline plants as well as further work in tank farms.

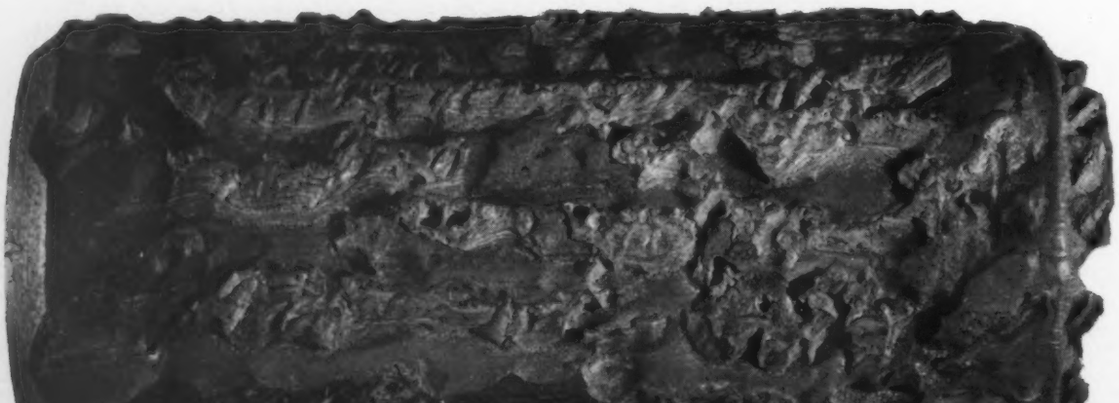


**FIGURE 9**
***A badly corroded pump shaft connection.***

# One Clay Tower Empty

## *But Efficiency Largely Improved*

PANHANDLE Refining Company, Wichita Falls, has been operating cracking equipment of Dubbs type for many years, and has processed pressure distillate vapors through Gray process clay-filled towers almost as long as cracking has been practiced in the plant. In order to obtain the requisite separation and specifications for finishing gasoline, it was formerly necessary to remove the spent clay from the towers frequently and refill with fresh fullers earth. The reason for frequent refilling had not been determined, but always when entering a vessel to clean and recondition before placement of the fresh charge, the supporting screens were found warped in various places, which indicated channeling of vapors through the clay beds.

One of the towers now used in the clay-treating process is part of the original installation, but the second tower is a reaction chamber borrowed from a revamped cracking plant, and installed to replace one of the original towers which was damaged in use several years ago. The screens used in the towers formerly were more or less conventional in weave, were made in segments and placed in the tower laid upon supports in the customary fashion. When reconditioning the towers late in 1936, it was decided that if a screen could be secured which was formed in a single sheet with only one radial separation provided for convenience in shipping and in introducing it into the tower, then the clay could be used for longer periods beause of lessened chance of damaging the supports when cleaning.

Two clay towers had been used in this plant for several years. In January 1937 the conventional and original Gray tower was filled with a fresh charge of clay. When the new screen was installed, a substantial plate was placed on the screen-supporting members, and this plate was perforated to permit free passage of vapors and polymers. The replacement tower, or second in the series, was cleaned at the same time but was left empty to act as a "delayed" treating vessel.

The reconditioned tower was charged with 25 tons of fresh clay. The piping was not disturbed, so that the vapors could travel in series from the bubble tower through both clay towers to the final fractionating column. Originating in the bubble tower the vapors at 430°F. pass through the clay treating system and are fractionated to end point in the final fractionating column.

Polymers are produced from both of the Gray process towers. The first tower which is charged with clay separates a material almost black in color, which is trapped to the fuel oil flash chamber with no further processing. The unfilled tower of the clay-treating system produced an amber-colored polymer stream, almost equal in volume to the production of the clay-filled tower, and this material is returned to the cracking unit bubble tower for reprocessing.

Approximately 830 barrels of pressure-distillate vapors produced from North Texas crude, are passed daily from the main fractionating column and finished to specifications as motor fuel. The flow of the vapors begins in the main column, passing to the top of the first clay tower, which is charged with fullers earth. Vapors flowing downward through the bed of clay are evenly distributed through the clay, which is supported and in which channeling is prevented by the improved screen installation and the reinforced supporting equipment.

Instead of handling one stream of dark polymer liquid (which was formerly pumped back into the bubble column to contact the hot vapors from the cracking plant, to be revaporized and passed with the pressure distillate vapors back to the clay bed) the clay treating system now produced two streams. Under the new system the dark polymers are removed from the clay-filled tower and are pumped into the fuel-oil stream. The second, or empty tower, where apparently the reaction and formation of additional polymers continues, yields a stream much lighter in color. These polymers as accumulated are pumped to the main bubble column and reprocessed with the vapors coming from the cracking unit. It was learned from laboratory experiments that these polymers could be used again in this manner without degrading the finished product.

In the former operation of the two clay-filled towers, it was the practice to wash the clay beds with gasoline frequently, and to steam the filled towers to remove any polymers that might be held in the clay-treating material. Since revamping the treating plant, steam has not been used, nor has gasoline been pumped through the bed of clay. The original charge of 25 tons of fullers earth, placed in the tower in January, 1937, is still in use, without cleaning, steaming or washing with gasoline and has given no evidence of channeling.

This sample was taken from the stream after the single clay-filled tower had been in operation for about 16 months, and after it had treated over 12,000 barrels of gasoline per ton of clay, or a total of over 300,000 barrels treated for the original charge.

# *Tentative Equilibrium* Constants *for* Light Hydrocarbons

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**THE prediction of the composition of co-existing gas and liquid phases is of value in many of the operations encountered in the production and refining of petroleum. Equilibrium constants are helpful in this regard, and afford one of the most practical approaches to this complex problem. It is necessary, however, that the equilibrium constants employed apply to the particular system at the state in question. At the present state of knowledge it is impossible to predict accurately the equilibrium constants for many of the conditions of pressure and temperature encountered in practice. The results reported here are to be considered as a tentative correlation of the available data relating to the equilibrium constants of the light hydrocarbons under the conditions of pressure and temperature commonly encountered in the production of petroleum from underground reservoirs. There is need for much more experimental work upon a variety of hydrocarbon systems before it will be possible to predict with certainty the equilibrium constants for even the simplest paraffin hydrocarbons in many of the systems with which the petroleum technologist must deal.**

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**The statements and opinions expressed herein are those of the authors, and should not be construed as an official action or opinion of the institute nor of this publication.**

THE prediction of the composition of co-existing gas and liquid phases is of value in many of the operations encountered in the production and refining of petroleum. Equilibrium constants are helpful in this regard, and afford one of the most practical approaches to this complex problem. It is necessary, however, that the equilibrium constants employed apply to the particular system at the state in question. At the present state of knowledge it is impossible to predict accurately the equilibrium constants for many of the conditions of pressure and temperature encountered in practice. The results reported here are to be considered as a tentative correlation of the available data relating to the equilibrium constants of the light hydrocarbons under the conditions of pressure and temperature commonly encountered in the production of petroleum from underground reservoirs. There is need for much more experimental work upon a variety of hydrocarbon systems before it will be possible to predict with certainty the equilibrium constants for even the simplest paraffin hydrocarbons in many of the systems with which the petroleum technologist must deal.

The use of equilibrium constants for the prediction of the composition of co-existing gas and liquid phases was brought to the attention of the petroleum industry by the work of Souders, Selheimer, and Brown.[1] They reported information concerning the effect of pressures as high as 500 pounds per square inch, and of temperatures over the range normally encountered in refinery practice. These results were based almost entirely upon the laws of ideal solution and, hence, could not be expected to apply with accuracy to systems which deviated significantly from this behavior. W. K. Lewis and coworkers[2, 3] have published information pertaining to the composition of co-existing phases, which was based in part upon the laws of ideal solution and in part upon the experimental data that were then available. Both of these investigators presented values only as a function of pressure and temperature, and assumed that the effect of the nature and amount of each of the other components present had a negligible effect upon the behavior of the component in question. Recently, Sherwood[4] tabulated constants for the paraffin hydrocarbons from methane through *n*octane, the values being based for the most part upon the laws of ideal solution. Katz[5] has published the results of experimental investigation of the effect of pressure and temperature upon the equilibrium constants of the paraffin hydrocarbons from methane through the hexanes in mixtures of Mid-Continent crude oil and natural gas of unknown proportions. This work affords the only experimental data upon naturally-occurring hydrocarbon systems which are at present available to the authors. Buckley[6] has reported the equilibrium constant for methane in naturally-occurring hydrocarbon systems as a function of pressure and temperature. There is available also a reasonable amount of information upon the behavior of binary hydrocarbon systems, which is of value in predicting the behavior of complex systems. Data of this nature have been employed along with the work of Katz[5] in developing the correlation presented in this paper.

## GENERAL CONSIDERATIONS

The equilibrium constant may be defined as the ratio of the mole fraction of a component in the gas phase to its mole fraction in a co-existing liquid phase, the two phases being at equilibrium. It has been known under other names, such as "vapor-liquid vaporization constant."[5] The term "constant" has been retained in the present discussion because of its widespread use, rather than from any implication of the constancy of this quantity with respect to any of the variables affecting the state of the system. It can be shown from the

phase rule that the equilibrium constant of any component is a function of all the variables which must be stipulated in order to define the state of each of the phases. Therefore, any method of prediction must of necessity be approximate unless all the variables which affect the state of the phases are taken into account. Serious uncertainties in the evaluation of the equilibrium constant under certain conditions of pressure and temperature may result if this is not done.

If it is assumed that a system follows the laws of ideal solution[7] at all of the pressures and temperatures involved, the equilibrium constant of each of the components may be predicted (in some cases with difficulty) from the behavior of the pure component. In such systems the partial specific volume[8] * of each component and the partial specific internal energy must be equal, respectively, to the specific volume and the specific internal energy of the pure component in the same type of phase and at the same pressure and temperature. No actual system follows this behavior exactly, but many hydrocarbon systems approximate it sufficiently well that predictions of behavior based upon the laws of ideal solution are of value for engineering purposes at some pressures and temperatures. In general, hydrocarbon systems appear to follow such ideal behavior when the components are not greatly different from one another in chemical nature and molecular weight. In the case of gases, the agreement with the laws of ideal solution at pressures in the vicinity of atmospheric is sufficiently good to be satisfactory for nearly all engineering purposes except those requiring the highest accuracy. At high pressures such large deviations from ideal solution are encountered that such calculations of the volumetric or even the phase behavior of the lighter components that are normally encountered in production practice are of little value.

It is sufficient to consider the equilibrium constant of a given component to be a function of the prevailing pressure, temperature, and the composition and chemical nature of the system as a whole. Unfortunately there are insufficient experimental data available at present to permit such a complete correlation for any of the components. Because of this scarcity of facts, simplifications which introduce uncertainties of unknown magnitude in the resulting correlation must be made. This causes errors in the predicted equilibrium constant whenever the conditions digress significantly from those covered by the experimental work upon which the correlation is based.

It has been necessary to restrict the present correlations to a consideration of the effect of pressure and temperature, and of the molecular weight and chemical nature, of the heavier components present in the system. This procedure completely neglects the effect of the presence of varying amounts of the components from methane through the pentanes upon the equilibrium behavior of any individual component in question. This is known to introduce uncertainty; but at present, except in a few instances, it is impossible to indicate even qualitatively the magnitude of this effect.

## THE LESS-VOLATILE CONSTITUENT

The composition of a multi-component system can only be defined completely if the nature and amount of each of the components (molecular species) are specified. Strictly speaking, the equilibrium constant for each component at a given pressure and temperature would depend, therefore, upon the nature and amount of each of the other components present. As mentioned above, the treatment has necessarily been simplified, and the equilibrium constants are considered only as functions of the average chemical nature and molecular weight of the whole group of components heavier than pentane which is contained in the system.

This composite material will be called the "less-volatile constituent." The oil which, in the normal course of production operations, is separated from the well production at the surface may be considered to approximate the less-volatile constituent in such systems, when information is not available regarding the properties of the pentane-free oil. Generally, such oil is roughly in equilibrium with a hydrocarbon gas under the conditions of surface separation.

The present approach assumes that the equilibrium constant of a component at a given pressure and temperature is dependent upon the average properties of the less-volatile constituent. The average molecular weight of the less-volatile constituent may be ascertained by a cryoscopic method[9] with sufficient accuracy for the purpose at hand, and appears to be a more fundamental index of the average properties of the less-volatile constituent of a given chemical nature than are such quantities as specific gravity or viscosity.

There have been developed a number of empirical parameters which may be used as indices of the chemical nature of a hydrocarbon liquid of relatively low volatility. The viscosity-gravity factor developed by Hill and Coats[10] appears to be a reasonable device for such purposes. If this factor is combined with the relations developed by McCluer and Fenske,[11] it is possible to predict approximately the relative amounts of naphthenic and paraffinic materials that are present in the liquid. This factor cannot be applied to systems which are nearly pure paraffins or naphthenes, but appears to cover many conditions that are encountered in petroleum production practice.

The viscosity-gravity factor $A$, developed by Hill and Coats,[10] is related by the following expression to the viscosity $\eta'$ expressed in Saybolt Universal seconds at 100°F., and the specific gravity $G$ relative to water at 60°F.

$$A = \frac{G - 0.10752 \log_{10} (\eta' - 38)}{1 - 0.10 \log_{10} (\eta' - 38)} \quad \ldots\ldots\ldots (1)$$

In a previous paper by the authors[18] it was found empirically that the equilibrium constants applying to a system having a less-volatile constituent with a viscosity-gravity factor of 0.82 could be corrected by use of the following equation so as to apply to systems having less-volatile constituents with other viscosity-gravity factors:

$$K_A = K_{0.82}[1 + 1.87 (A - 0.82) + 13 (A - 0.82)^2] \ldots . (2)$$

The above expression indicates that this correction is solely a function of the viscosity-gravity factor, and is independent of all other parameters. This undoubtedly is only an approximation, but appears to describe the variations in the equilibrium constant with the chemical nature of the less-volatile constituent as well as it is known from present experimental data. The use of such an index of composition disregards the presence of any aromatic material in the less-volatile constituent, and only indicates the relative amounts of naphthenic and paraffinic materials. The neglect of aromatic material does not vitiate the use of the viscosity-gravity factor as an index to composition in many cases, but care is required in the application of such methods to

* The partial specific volume of a component may be defined as the change in volume of a relatively large system due to the addition of a unit weight of that component under specified conditions, such as temperature, pressure and composition. It is necessary that the mass of the system chosen be sufficiently large that no appreciable change in composition results from this addition.

certain situations where relatively large quantities of aromatic compounds may be present.

## CRITICAL BEHAVIOR

For present purposes the "critical state" may be defined as that state at which each of the intensive properties of the two phases become continuously identical. From this definition it is seen that the equilibrium constant for each of the components must be unity at this point. Inasmuch as the location of the critical state is a function of the chemical nature and composition of the system, it is necessary to take this into account in the prediction of equilibrium constants at elevated pressures.

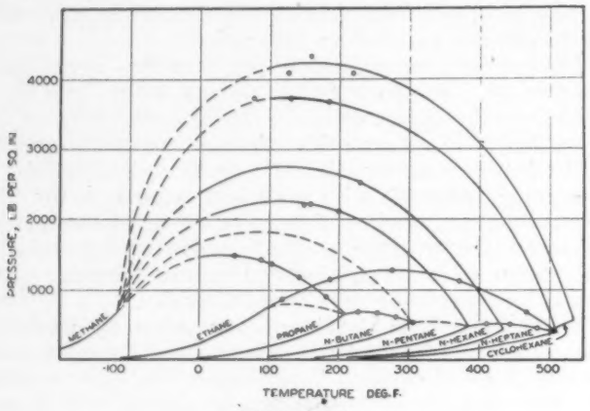


**FIGURE 1**

***The Loci of the critical states for a number of binary hydrocarbon systems on a pressure-temperature diagram.***

Figure 1 presents the variation in critical pressure with temperature for a number of binary hydrocarbon systems. Figure 1 is based upon experimental information concerning the behavior of the following binary systems: methane-propane,[12] methane-*n*butane, methane-*n*pentane,[13] methane-*n*hexane,[13] methane-*n*heptane,[14] methane-cyclohexane,[13] propane-*n*butane,[15] *n*pentane-*n*heptane,[16] ethane-*n*heptane.[17] Although these data do not cover all of the possible binary systems obtainable from the above-mentioned components, they do indicate roughly the effect of the nature of the components upon the magnitude of the critical pressures and temperatures involved. These data indicate that the farther apart are the critical temperatures of the two components, the greater is the maximum critical pressure attained by the system. For example, the maximum critical pressure of the pentane-*n*heptane system is only a few pounds per square inch above the critical pressure of heptane, while the maximum critical pressure of the methane-*n*heptane system is nearly 4000 pounds per square inch above the critical pressure of methane. This rapid increase in the maximum critical pressure of binary systems containing methane, with an increase in the molecular weight of the other component, indicates that critical pressures in excess of 7000 pounds per square inch would be expected for the binary hydrocarbon systems whose less-volatile components had a molecular weight comparable to that of the crude oils normally encountered in practice. Such a critical state is probably never reached, due to the formation of a second (possibly asphaltic liquid phase at the higher pressures. Under these circumstances the critical behavior becomes exceedingly complex, and there is insufficient experimental information available at present even to surmise which of the many possible types of phenomena will be encountered in the case of the ordinary crude-oil-natural-gas systems. The data presented in Figure 1 indicate that naphthenic systems as typified by the behavior of the methane-cyclohexane system exhibit higher critical pressures than are encountered in comparable paraffin systems.

It is necessary to predict the critical pressures of the more volatile naturally-occurring hydrocarbon systems, containing a relatively small amount of asphaltic material, on the basis of the average properties of the components other than methane. This procedure is equivalent to the assumption that such naturally-occurring systems may be treated for this purpose as binary systems made up of one complex component and methane. Figure 2 presents the critical pressure of binary hydrocarbon systems as a function of the average molecular weight of this complex component, i. e., all of the components other than methane taken as one in this case. The curves were based upon the assumption of a linear relation between the critical pressure and the relative amount of paraffinic and naphthenic material present. It is somewhat arbitrary in nature, and should be regarded as semi-quantitative—possibly requiring extensive modification as more experimental information accumulates. Again it must be emphasized that the presence of aromatic materials has been disregarded in the preparation of Figure 2. In general, aromatic materials tend to increase the critical pressure if other conditions are comparable.

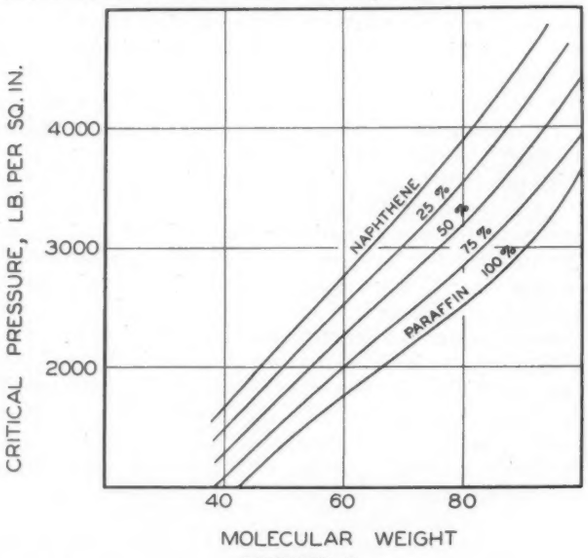


**FIGURE 2**

***Effect of the molecular weight of the other component upon the critical pressure of binary hydrocarbon systems containing methane at 160°F.***

It is desirable to point out that the critical pressures referred to in Figures 1 and 2 are the true critical pressures of the system, and should not be confused with the so-called pseudo-critical points[19] which have been proposed as a means of correlating the volumetric behavior of hydrocarbon mixtures. Pseudo-critical pressures and temperatures are not of great value in determining the equilibrium constants, inasmuch as it is only the true critical state which exerts a marked influence upon the equilibrium constants.

## GENERAL APPROACH TO CORRELATION

In the light of the foregoing discussions, it is possible to summarize briefly the general methods that have been employed in correlating the equilibrium

**TABLE 1**
**Equilibrium Constants for Methane**

| Pressure (Lb. per Sq. In., Absolute) | Molecular Weight=60 | | | Molecular Weight=75 | | | Molecular Weight=100 | | | Molecular Weight=200 | | | Molecular Weight=300 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100° F. | 160° F. | 220° F. | 100° F. | 160° F. | 220° F. | 100° F. | 160° F. | 220° F. | 100° F. | 160° F. | 220° F. | 100° F. | 160° F. | 220° F. |
| 14.7 | ..... | ..... | ..... | 224* | 247 | 248 | 247 | 285 | 293 | 259 | 276 | 287 | 203 | 226 | 228 |
| 20 | ..... | ..... | ..... | 165 | 181 | 182 | 181 | 210 | 216 | 190 | 203 | 211 | 149 | 166 | 168 |
| 40 | ..... | ..... | ..... | 82.8 | 90.9 | 91.5 | 91.0 | 105 | 108 | 95.5 | 102 | 106 | 75.1 | 83.4 | 84.2 |
| 60 | ..... | ..... | ..... | 55.4 | 60.8 | 61.3 | 60.9 | 70.1 | 72.1 | 63.9 | 68.2 | 70.7 | 50.4 | 55.9 | 56.4 |
| 100 | ..... | ..... | ..... | 33.5 | 36.7 | 37.1 | 36.9 | 42.2 | 43.3 | 38.6 | 41.2 | 42.6 | 30.6 | 33.8 | 34.2 |
| 150 | ..... | ..... | ..... | 22.49 | 24.72 | 25.0 | 24.74 | 28.2 | 29.0 | 25.9 | 27.7 | 28.7 | 20.68 | 22.87 | 23.08 |
| 200 | ..... | ..... | ..... | 17.06 | 18.63 | 18.96 | 18.77 | 21.31 | 21.84 | 19.58 | 21.04 | 21.71 | 15.72 | 17.32 | 17.53 |
| 300 | 10.70 | ..... | ..... | 11.59 | 12.58 | 12.89 | 12.75 | 14.30 | 14.67 | 13.26 | 14.27 | 14.69 | 10.78 | 11.80 | 11.96 |
| 400 | 8.12 | ..... | ..... | 8.86 | 9.56 | 9.84 | 9.73 | 10.80 | 11.08 | 10.05 | 10.88 | 11.18 | 8.31 | 9.04 | 9.19 |
| 500 | 6.56 | 6.80 | 7.13 | 7.20 | 7.74 | 8.00 | 7.91 | 8.71 | 8.93 | 8.22 | 8.86 | 9.09 | 6.82 | 7.40 | 7.53 |
| 750 | 4.48 | 4.60 | 4.89 | 5.01 | 5.32 | 5.52 | 5.48 | 5.94 | 6.06 | 5.72 | 6.18 | 6.30 | 4.84 | 5.21 | 5.33 |
| 1,000 | 3.42 | 3.46 | 3.66 | 3.90 | 4.10 | 4.24 | 4.29 | 4.55 | 4.61 | 4.48 | 4.84 | 4.91 | 3.86 | 4.14 | 4.23 |
| 1,250 | 2.76 | 2.72 | 2.89 | 3.20 | 3.35 | 3.44 | 3.51 | 3.71 | 3.75 | 3.75 | 4.04 | 4.08 | 3.26 | 3.49 | 3.58 |
| 1,500 | 2.30 | 2.21 | 2.30 | 2.73 | 2.81 | 2.87 | 3.00 | 3.16 | 3.16 | 3.27 | 3.50 | 3.53 | 2.86 | 3.05 | 3.15 |
| 1,750 | 1.93 | 1.80 | 1.80 | 2.36 | 2.40 | 2.44 | 2.63 | 2.76 | 2.75 | 2.93 | 3.12 | 3.13 | 2.57 | 2.74 | 2.84 |
| 2,000 | 1.62 | 1.43 | ..... | 2.07 | 2.06 | 2.08 | 2.34 | 2.45 | 2.43 | 2.69 | 2.83 | 2.83 | 2.34 | 2.50 | 2.60 |
| 2,500 | ..... | ..... | ..... | 1.60 | 1.52 | 1.48 | 1.95 | 2.03 | 1.97 | 2.36 | 2.42 | 2.40 | 2.02 | 2.15 | 2.25 |
| 3,000 | ..... | ..... | ..... | 1.17 | ..... | ..... | 1.66 | 1.74 | 1.66 | 2.14 | 2.15 | 2.09 | 1.78 | 1.90 | 2.00 |

* These values apply directly only to systems with a less-volatile constituent having a viscosity-gravity factor of 0.82.

constants for the hydrocarbons that are considered in this paper. The equilibrium constants have been treated as functions of the prevailing pressure, temperature, and the nature and molecular weight of the less-volatile constituent. It has only been possible to include any specific treatment of the effects of the less-volatile constituent in the cases of methane and ethane. Equilibrium constants of all other components have been considered as functions of pressure and temperature only. The procedure followed neglects the effect of the components from methane through the pentanes upon the equilibrium behavior of any individual component in the system, and also fails to take into account the effect of the chemical nature of components other than the naphthenes and the paraffins. The effect of the relative amount of each of the components in the system has been neglected in all cases.

## METHANE

Methane plays one of the most important roles in the volumetric and phase behavior of naturally-occurring hydrocarbon mixtures. For this reason it is important to evaluate the equilibrium constant for this material as accurately as possible. Minor errors in such an evaluation may completely overshadow much larger uncertainties in equilibrium constants for the components of greater molecular weight, which play a less important part in determining the volumetric behavior of the system. Fortunately, there is a reasonable amount of experimental information available concerning the phase behavior of methane.

These data have been collected and a correlation prepared, which is described in a recent publication[18] by the authors. The results of this correlation are reported in Table 1, which gives values of the equilibrium constant for a series of pressures and temperatures for systems with less-volatile constituents of varying molecular weight, but with a viscosity-gravity factor of 0.82.

The equilibrium constants for systems with less-volatile constituents having viscosity-gravity factors other than 0.82 may be ascertained by use of equation (2). The value of $K_{08.2}$ at the prevailing pressure, temperature, and molecular weight of the less-volatile constituent can be obtained from Table 1. From a knowledge of the viscosity-gravity factor as determined from equation (1) the equilibrium constant for the particular system in question may then be obtained from equation (2).

This procedure is somewhat complicated, but it is believed that the greater accuracy obtained from a consideration of the molecular weight and viscosity-gravity factor of the less-volatile constituent more than justifies its use. Due to the limitations of the use of viscosity-gravity factors for materials of relatively low molecular weight, it is necessary to empoly a more or less arbitrary correction to the equilibrium constants recorded in Table 1 for such materials. The constants apply directly to systems with a less-volatile constituent having a viscosity-gravity factor of 0.82, this corresponding to material which is approximately 50 mole percent naphthenic. It is possible, therefore, if the chemical nature of the less-volatile constituent of low molecular weight is known, to make an arbitrary correction to the values recorded in Table 1. In the case of systems which are substantially paraffinic, recourse to the original data[18] pertaining to the behavior of the various binary systems is helpful.

Due to the rapid changes in the equilibrium constants with pressure, it is difficult to interpolate from tabulated data with respect to this variable. If, on the other hand, the product of the fugacity of pure methane gas and the equilibrium constant is employed in this connection, a much more accurate interpolation is possible. Figure 3 presents this product as a function of pressure for a series of temperatures for a system having a less-volatile constituent with a viscosity-gravity factor of 0.82 and a molecular weight of 200. From thermodynamic considerations it can be shown that this product is equal to the fugacity of methane in the liquid phase. If the volume of the component in the liquid phase is neglected, ideal solutions predict that the fugacity in the liquid phase should be a constant which is independent of pressure and temperature.

Figure 3 indicates, in a way, the deviation of the behavior of methane from that predicted by the laws of ideal solution insofar as its volumetric behavior is concerned. At infinite dilution, i. e., at a pressure in the vicinity of zero, a limiting value of the fugacity of methane in the liquid phase may be obtained. It is not within the scope of this paper to discuss the thermo-dynamic applicability of such quantities, and Figure 3 is to be considered only as an interpolating device insofar as its present use is concerned.

## ETHANE

The experimental background for the phase behavior of ethane in simple and complex hydrocarbon

systems is somewhat more limited than that available for methane. Kay[17] has reported information concerning the phase behavior of the ethane-*n*heptane system throughout most of the range of temperatures and pressures where the existence of two phases is possible. This work affords a satisfactory source of information concerning the equilibrium constant for ethane in a less-volatile constituent of relatively low molecular weight. Katz[5] determined the equilibrium constant for ethane in a system consisting of a Mid-Continent oil and gas at pressures up to 3500 pounds per square inch at 40, 120, and 200°F. Sage, Davies, Sherborne, and Lacey[20] determined the volumetric and a part of the phase behavior of mixtures of ethane and a heavy water-white oil with an average molecular weight of 337. Neglecting the presence of any of the components of the oil in the gas phase, it is possible to calculate values of the equilibrium constant for ethane in this system as a function of temperature and pressure.

These data permit the evaluation of the effect of the molecular weight of the less-volatile constituent upon the equilibrium constant, but do not indicate the effect of its chemical nature. For this reason it was necessary to prepare the correlation of the equilibrium constant of ethane on the basis that it is a function only of pressure, temperature, and the molecular weight of the less-volatile constituent.

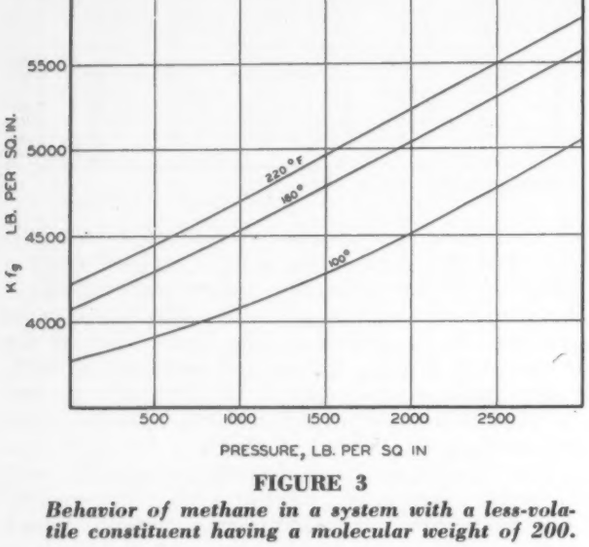


**FIGURE 3**

***Behavior of methane in a system with a less-volatile constituent having a molecular weight of 200.***

Figure 4 presents the variation in the equilibrium constant for ethane with the molecular weight of the less-volatile constituent at several pressures at 100°F. The data indicate that there is a regular increase in the equilibrium constant with the molecular weight of the less-volatile constituent.

These data indicate a reasonable agreement at the lower pressures and temperatures with values based upon the laws of ideal solution.[4] It is to be expected that appreciable divergences from this behavior will be encountered at higher temperatures which are appreciably above the critical temperature of ethane. The rapid increase in the equilibrium constant with a decrease in pressure makes extrapolation, or even interpolation, difficult in this region. If, however, the product of the fugacity and the equilibrium constant is plotted as a function of pressure, much of the difficulty is overcome. Figure 5 depicts this product as a function of pressure for three temperatures for a system having a less-volatile constituent with a molecular weight of 200. The use of this product, which, in the vicinity of zero pressure, corresponds to the fugacity of the liquid, affords a useful method of predicting the deviation of the solution from the laws of ideal solution at infinite dilution of ethane. The use of such a device is of value in ascertaining the volumetric behavior of these systems, as it indicates the limiting value of the partial volume of that

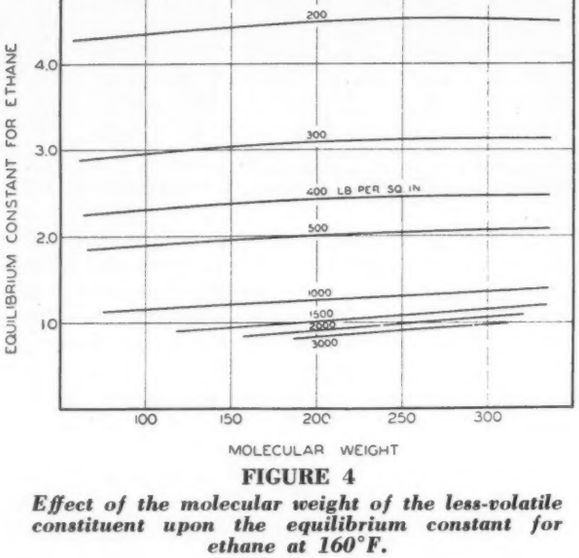


**FIGURE 4**

***Effect of the molecular weight of the less-volatile constituent upon the equilibrium constant for ethane at 160°F.***

**TABLE 2**
**Equilibrium Constants for Ethane**

| Pressure (Lb. per Sq. In., Absolute) | Molecular Weight=100 | | | Molecular Weight=200 | | | Molecular Weight=300 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 100° F. | 160° F. | 220° F. | 100° F. | 160° F. | 220° F. | 100° F. | 160° F. | 220° F. |
| Atmospheric | 37.1 | 56.5 | 75.6 | 38.7 | 57.7 | 77.2 | 41.2 | 56.9 | 73.7 |
| 20 | 27.3 | 41.5 | 55.6 | 28.5 | 42.5 | 56.9 | 30.3 | 41.9 | 54.2 |
| 40 | 13.8 | 20.9 | 27.8 | 14.4 | 21.4 | 28.6 | 15.3 | 21.1 | 27.3 |
| 60 | 9.24 | 14.0 | 18.6 | 9.66 | 14.3 | 19.2 | 10.3 | 14.2 | 18.4 |
| 100 | 5.65 | 8.50 | 11.2 | 5.88 | 8.71 | 11.7 | 6.26 | 8.66 | 11.2 |
| 150 | 3.84 | 5.73 | 7.56 | 3.99 | 5.90 | 7.88 | 4.26 | 5.90 | 7.67 |
| 200 | 2.93 | 4.35 | 5.72 | 3.06 | 4.49 | 6.04 | 3.28 | 4.52 | 5.90 |
| 300 | 2.05 | 2.96 | 3.89 | 2.13 | 3.09 | 4.13 | 2.27 | 3.15 | 4.13 |
| 400 | 1.61 | 2.30 | 2.96 | 1.66 | 2.41 | 3.22 | 1.79 | 2.46 | 3.23 |
| 500 | 1.35 | 1.90 | 2.42 | 1.38 | 2.00 | 2.68 | 1.50 | 2.07 | 2.71 |
| 750 | 1.04 | 1.35 | 1.70 | 1.04 | 1.46 | 1.93 | 1.16 | 1.56 | 2.02 |
| 1,000 | ..... | 1.09 | 1.35 | 0.930 | 1.22 | 1.59 | 1.06 | 1.33 | 1.69 |
| 1,250 | ..... | ..... | 1.13 | 0.868 | 1.09 | 1.37 | 1.01 | 1.21 | 1.49 |
| 1,500 | ..... | ..... | ..... | 0.811 | 1.01 | 1.24 | 0.974 | 1.15 | 1.38 |
| 1,750 | ..... | ..... | ..... | 0.775 | 0.954 | 1.14 | 0.946 | 1.11 | 1.29 |
| 2,000 | ..... | ..... | ..... | 0.755 | 0.913 | 1.08 | 0.932 | 1.07 | 1.23 |
| 2,500 | ..... | ..... | ..... | 0.741 | 0.855 | 0.995 | 0.928 | 1.02 | 1.13 |
| 3,000 | ..... | ..... | ..... | 0.740 | 0.830 | 0.945 | 0.930 | 0.970 | 1.06 |

component at infinite dilution—a quantity which is difficult to evaluate experimentally.

## PROPANE

The available experimental data for propane are limited to the directly-determined equilibrium constants reported by Katz,[5] and to some values for the equilibrium constant for propane in the methane-propane system.[12] These data were not considered sufficiently complete to permit a correlation on the basis of the properties of the less-volatile constituent. For this reason the values for propane which are reported in Table 3 are based primarily upon the experimental measurements of Katz.[5] Because of some inconsistencies in these data at pressures in the neighborhood of 1 atmosphere, they have been modified arbitrarily to conform more closely to the general behavior predicted from the laws of ideal solution. This modification only amounted to approximately 5 percent and, therefore, was probably not greatly beyond the experimental uncertainty of measurement in this region. The behavior of propane in an ideal solution was predicted from values of the fugacity of pure propane which have been reported elsewhere.[21]

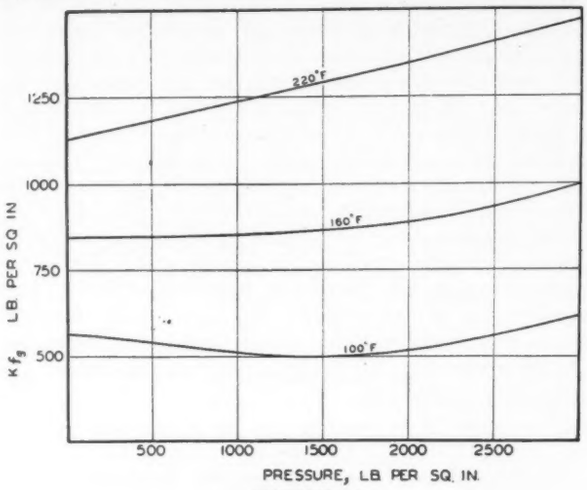


**FIGURE 5**

***Behavior of ethane in a system with a less-volatile constituent having a molecular weight of 200.***

The disregard of the effect of the physical and chemical properties of the less-volatile constituent introduces an added uncertainty into the equilibrium constants for propane. Fortunately, propane does not play as important a part in determining the volumetric behavior of naturally-occurring hydrocarbon systems as do methane and ethane. Therefore, a somewhat larger uncertainty as to the proper value of the equilibrium constant does not introduce a comparable error in the predicted volumetric behavior. In this connection, Table 7 has been prepared, in which are recorded equilibrium constants for propane based upon the experimental data for the methane-propane system. A comparison of the data reported in Table 3 and in Table 7 indicates that, at the same pressure and temperature, there is a marked difference between the two constants—especially at the higher pressures. The larger discrepancies encountered at the higher pressures are due primarily to the relatively low critical pressures exhibited by mixtures of methane and propane at the temperature in question. This indicates that it is necessary to modify arbitrarily the values reported in Table 3 in such instances that the critical pressure of the system in question is below 4000 pounds per square inch. In most instances for systems containing methane, this will only be encountered when the less-volatile constituent has a molecular weight less than 100, as was indicated in Figure 1. However, in the case of systems which do not contain appreciable quantities of methane, critical pressures below 1000 pounds per square inch are common, and care must be exercised in the use of the equilibrium constants of Table 3 for these systems at the higher pressures.

## THE BUTANES

The useful experimental data that are available concerning the equilibrium constants for either *n*-butane or *iso*butane at elevated pressures are again limited to the measurements by Katz.[5] In this case no differentiation was made between the behavior of *n*butane and *iso*butane, and for this reason the values reported in the lower part of Table 4 apply to both substances. This procedure introduces uncertainty, especially in the case of systems in which there is a markedly different distribution between the relative amounts of *n*butane and *iso*butane present in the system in question and those present in the natural-gas-crude-oil system investigated by Katz.[5]

At the lower pressures in the neighborhood of atmospheric, it is believed that ideal solutions are sufficiently descriptive of the individual behavior of the two separate butanes to replace the combined values referred to above, and are used as the basis for the equilibrium constants for *n*butane and *iso*butane recorded in the upper part of Table 4. The necessary experimental information concerning the behavior of *n*butane and *iso*butane have been taken from publications of the authors.[22, 23] The values of the constant for the combined butanes based upon the measurements of Katz[5] fall nearly mid-way between the individual values obtained from ideal-solution considerations. This agreement indicates that naturally-occurring hydrocarbon systems may follow the laws of ideal solutions reasonably well at low pressures insofar as the phase behavior of the butanes is concerned.

Again it must be emphasized that complete disregard of the effect of the nature of the less-volatile constituent, and of the effect of the presence of varying amounts of other volatile components, has introduced uncertainty into the application of the equilibrium constants recorded in Table 4. Errors from

**TABLE 3**

**Equilibrium Constants for Propane**

| Pressure (Lb. per Sq. In., Absolute) | 70° F. | 100° F. | 130° F. | 160° F. | 190° F. | 220° F. |
|---|---|---|---|---|---|---|
| 14.7 | 8.18 | 11.8 | 16.1 | 21.0 | 26.9 | 33.3 |
| 20 | 6.03 | 8.65 | 11.9 | 15.6 | 19.8 | 24.6 |
| 40 | 3.06 | 4.38 | 6.06 | 7.89 | 10.0 | 12.4 |
| 60 | 2.10 | 2.97 | 4.05 | 5.27 | 6.68 | 8.32 |
| 100 | 1.27 | 1.82 | 2.46 | 3.23 | 4.12 | 5.05 |
| 150 | 0.871 | 1.24 | 1.68 | 2.20 | 2.79 | 3.39 |
| 200 | 0.680 | 0.951 | 1.28 | 1.68 | 2.14 | 2.58 |
| 300 | 0.481 | 0.670 | 0.902 | 1.18 | 1.50 | 1.79 |
| 400 | 0.394 | 0.537 | 0.716 | 0.934 | 1.17 | 1.43 |
| 500 | 0.343 | 0.465 | 0.617 | 0.795 | 0.994 | 1.23 |
| 750 | 0.300 | 0.396 | 0.506 | 0.635 | 0.787 | 0.966 |
| 1,000 | 0.294 | 0.382 | 0.476 | 0.584 | 0.705 | 0.843 |
| 1,250 | 0.304 | 0.386 | 0.471 | 0.564 | 0.664 | 0.771 |
| 1,500 | 0.324 | 0.397 | 0.475 | 0.557 | 0.640 | 0.726 |
| 1,750 | 0.347 | 0.413 | 0.483 | 0.558 | 0.632 | 0.698 |
| 2,000 | 0.373 | 0.433 | 0.498 | 0.565 | 0.628 | 0.681 |
| 2,500 | 0.434 | 0.480 | 0.528 | 0.582 | 0.632 | 0.668 |
| 3,000 | 0.501 | 0.535 | 0.570 | 0.607 | 0.644 | 0.675 |

**TABLE 4**
**Equilibrium Constants for the Butanes**

| Pressure (Lb. per Sq. In., Absolute) | 70° F. | 100° F. | 130° F. | 160° F. | 190° F. | 220° F. |
|---|---|---|---|---|---|---|
| | *Iso*Butane | | | | | |
| 14.7 | 2.87* | 4.37 | 6.29 | 8.67 | 11.4 | 14.3 |
| 20 | 2.13 | 3.26 | 4.67 | 6.40 | 8.42 | 10.6 |
| 40 | ..... | 1.70 | 2.41 | 3.30 | 4.33 | 5.37 |
| 60 | ..... | ..... | ..... | 2.26 | 2.97 | 3.72 |
| 100 | ..... | ..... | ..... | ..... | ..... | 2.35 |
| | *n*Butane | | | | | |
| 14.7 | 2.04* | 3.26 | 4.85 | 6.85 | 9.29 | 11.3 |
| 20 | 1.52 | 2.42 | 3.60 | 5.09 | 6.87 | 8.41 |
| 40 | ..... | 1.26 | 1.87 | 2.64 | 3.54 | 4.50 |
| 60 | ..... | ..... | ..... | 1.82 | 2.43 | 3.16 |
| 100 | ..... | ..... | ..... | ..... | ..... | 2.00 |
| | The Butanes | | | | | |
| 40 | 0.955 | ..... | ..... | ..... | ..... | ..... |
| 60 | 0.655 | 1.02 | 1.54 | ..... | ..... | ..... |
| 100 | 0.408 | 0.632 | 0.918 | 1.27 | 1.72 | ..... |
| 150 | 0.290 | 0.446 | 0.644 | 0.885 | 1.19 | 1.57 |
| 200 | 0.230 | 0.353 | 0.508 | 0.690 | 0.912 | 1.20 |
| 300 | 0.171 | 0.259 | 0.366 | 0.497 | 0.649 | 0.840 |
| 400 | 0.145 | 0.212 | 0.298 | 0.401 | 0.525 | 0.667 |
| 500 | 0.128 | 0.187 | 0.262 | 0.349 | 0.452 | 0.571 |
| 750 | 0.116 | 0.165 | 0.226 | 0.296 | 0.373 | 0.462 |
| 1,000 | 0.123 | 0.169 | 0.219 | 0.278 | 0.345 | 0.421 |
| 1,250 | 0.134 | 0.179 | 0.226 | 0.279 | 0.338 | 0.408 |
| 1,500 | 0.150 | 0.192 | 0.237 | 0.288 | 0.343 | 0.405 |
| 1,750 | 0.166 | 0.208 | 0.251 | 0.299 | 0.350 | 0.407 |
| 2,000 | 0.185 | 0.224 | 0.266 | 0.312 | 0.362 | 0.414 |
| 2,500 | 0.230 | 0.263 | 0.301 | 0.342 | 0.386 | 0.429 |
| 3,000 | 0.293 | 0.317 | 0.345 | 0.376 | 0.410 | 0.444 |

* Values in this part of the table are based upon ideal solutions.

this source become serious in the case of systems containing a less-volatile constituent of low molecular weight, whose properties are affected markedly by the presence of such components as methane and ethane.

## THE PENTANES

The values reported at the higher pressures in Table 5 for the pentanes are based entirely upon the measurements of Katz,[5] who reports the only data available to the authors concerning the equilibrium constants for the pentanes in naturally-occurring hydrocarbon systems at elevated pressures. It was considered worthwhile to differentiate between the behavior of *n*pentane and *iso*pentane on the basis of ideal solution at the lower pressures. These latter

**TABLE 5**
**Equilibrium Constants for the Pentanes**

| Pressure (Lb. per Sq. In., Absolute) | 70° F. | 100° F. | 130° F. | 160° F. | 190° F. | 220° F. |
|---|---|---|---|---|---|---|
| | *Iso*Pentane | | | | | |
| 14.7 | ..... | 1.3* | 2.2 | 3.3 | 4.6 | 6.4 |
| 20 | ..... | ..... | 1.7 | 2.5 | 3.5 | 4.7 |
| 40 | ..... | ..... | ..... | 1.2 | 1.8 | 2.4 |
| | *n*Pentane | | | | | |
| 14.7 | ..... | 1.06* | 1.74 | 2.68 | 3.90 | 5.45 |
| 20 | ..... | ..... | 1.30 | 1.99 | 2.90 | 4.04 |
| 40 | ..... | ..... | ..... | 1.05 | 1.52 | 2.08 |
| | The Pentanes | | | | | |
| 14.7 | 0.709 | ..... | ..... | ..... | ..... | ..... |
| 20 | 0.513 | 0.871 | ..... | ..... | ..... | ..... |
| 40 | 0.256 | 0.425 | 0.725 | ..... | ..... | ..... |
| 60 | 0.177 | 0.299 | 0.491 | 0.775 | 1.14 | 1.52 |
| 100 | 0.110 | 0.182 | 0.297 | 0.472 | 0.690 | 0.923 |
| 150 | 0.0791 | 0.132 | 0.213 | 0.328 | 0.476 | 0.640 |
| 200 | 0.0637 | 0.107 | 0.171 | 0.260 | 0.373 | 0.501 |
| 300 | 0.0508 | 0.0847 | 0.134 | 0.197 | 0.274 | 0.362 |
| 400 | 0.0461 | 0.0769 | 0.118 | 0.168 | 0.228 | 0.293 |
| 500 | 0.0448 | 0.0742 | 0.111 | 0.155 | 0.204 | 0.254 |
| 750 | 0.0452 | 0.0735 | 0.106 | 0.139 | 0.175 | 0.209 |
| 1,000 | 0.0516 | 0.0775 | 0.106 | 0.136 | 0.168 | 0.200 |
| 1,250 | 0.0586 | 0.0832 | 0.110 | 0.140 | 0.172 | 0.205 |
| 1,500 | 0.0664 | 0.0906 | 0.118 | 0.149 | 0.182 | 0.216 |
| 1,750 | 0.0769 | 0.101 | 0.129 | 0.162 | 0.196 | 0.231 |
| 2,000 | 0.0904 | 0.113 | 0.141 | 0.174 | 0.210 | 0.246 |
| 2,500 | 0.130 | 0.152 | 0.177 | 0.206 | 0.238 | 0.274 |
| 3,000 | 0.188 | 0.207 | 0.228 | 0.251 | 0.276 | 0.303 |

* Values in this part of the table are based upon ideal solutions.

equilibrium constants for *n*pentane were based upon fugacity values reported in another paper.[24] The values for *iso*pentane were taken from a compilation by Sherwood.[4] The satisfactory agreement of the directly-measured equilibrium constants for the pentanes with those predicted for *n*pentane and *iso*pentane on the basis of ideal solutions is a possible indication of the applicability of the latter values to the behavior of pentane in many of the naturally-occurring hydrocarbon systems encountered in practice.

The neglect of the effect of the less-volatile constituent and of the presence of other volatile components introduces an uncertainty comparable to that described in connection with propane and the butanes. However, uncertainty as to the proper value of the equilibrium constant of the pentanes does not cause as serious an effect on the volumetric behavior as do errors in the equilibrium constants of the more-volatile components. However, at low pressures these constants are of importance in calculating natural-gasoline recoveries and for other problems pertaining to the recovery of the pentanes from crude-oil and natural-gas production.

**TABLE 6**
**Equilibrium Constants for the Hexanes**

| Pressure (Lb. per Sq. In., Absolute) | 70° F. | 100° F. | 130° F. | 160° F. | 190° F. | 220° F. |
|---|---|---|---|---|---|---|
| 14.7 | 0.250* | 0.465 | 0.765 | 1.17 | 1.78 | 2.66 |
| 20 | 0.188 | 0.344 | 0.563 | 0.865 | 1.32 | 1.98 |
| 40 | 0.0982 | 0.178 | 0.288 | 0.445 | 0.676 | 1.02 |
| 60 | 0.0668 | 0.122 | 0.199 | 0.309 | 0.466 | 0.689 |
| 100 | 0.0427 | 0.0775 | 0.128 | 0.200 | 0.298 | 0.428 |
| 150 | 0.0310 | 0.0556 | 0.0927 | 0.145 | 0.212 | 0.301 |
| 200 | 0.0254 | 0.0453 | 0.0755 | 0.116 | 0.170 | 0.239 |
| 300 | 0.0201 | 0.0352 | 0.0574 | 0.0875 | 0.127 | 0.179 |
| 400 | 0.0176 | 0.0306 | 0.0489 | 0.0738 | 0.107 | 0.150 |
| 500 | 0.0165 | 0.0282 | 0.0446 | 0.0664 | 0.0966 | 0.135 |
| 750 | 0.0173 | 0.0277 | 0.0418 | 0.0610 | 0.0863 | 0.119 |
| 1,000 | 0.0210 | 0.0318 | 0.0461 | 0.0646 | 0.0871 | 0.114 |
| 1,250 | 0.0260 | 0.0382 | 0.0538 | 0.0725 | 0.0942 | 0.117 |
| 1,500 | 0.0326 | 0.0464 | 0.0635 | 0.0828 | 0.104 | 0.125 |
| 1,750 | 0.0410 | 0.0560 | 0.0736 | 0.0940 | 0.115 | 0.137 |
| 2,000 | 0.0513 | 0.0670 | 0.0857 | 0.106 | 0.129 | 0.151 |
| 2,500 | 0.0805 | 0.0957 | 0.114 | 0.137 | 0.159 | 0.181 |
| 3,000 | 0.124 | 0.138 | 0.155 | 0.174 | 0.194 | 0.217 |

* Values at pressures below 100 lb. per sq. in. are based for the most part upon ideal solutions.

## THE HEXANES

Katz[5] has reported values of the equilibrium constant of the hexanes as a function of pressure and temperature in mixtures of a Mid-Continent oil and gas. These data have been employed as a basis of the values reported in Table 6. However, the experimental values have been modified at pressures in the vicinity of 1 atmosphere in order to conform with the behavior predicted by ideal solutions.[4]

Table 8 presents values for the equilibrium constant for cyclohexane as a function of pressure and temperature in the methane-cyclohexane system. These values are based upon the measurements by Johnson,[14] and indicate the magnitude of the equilibrium constants for cyclohexane that might be expected in naturally-occurring hydrocarbon systems of relatively low average molecular weight.

## THE HEPTANES

The experimental work of Kay[17] upon the phase behavior of the ethane-heptane system gives information concerning the equilibrium constant for heptane in this system throughout a greater part of the range of pressures and temperatures in which the existence of two phases is possible. Johnson[14] investigated the phase behavior of the methane-*n*heptane system

**TABLE 7**
**Equilibrium Constants for Propane**

| Pressure (Lb. per Sq. In., Absolute) | Methane-Propane System | | | | |
|---|---|---|---|---|---|
| | 70° F. | 100° F. | 130° F. | 160° F. | 190° F. |
| 250 | 0.597 | 0.817 | ..... | ..... | ..... |
| 500 | 0.417 | 0.551 | 0.687 | 0.877 | ..... |
| 750 | 0.385 | 0.498 | 0.622 | 0.782 | 0.940 |
| 1,000 | 0.414 | 0.529 | 0.660 | 0.909 | ..... |
| 1,250 | 0.525 | 0.667 | ..... | ..... | ..... |

throughout a wide range of pressures at three temperatures. There is no experimental information available to the authors concerning the behavior of heptane in naturally-occurring hydrocarbon systems.

The conditions encountered in the above-mentioned investigations were sufficiently different from those related to most naturally-occurring systems to introduce serious uncertainty into their direct application to production problems. The values for the equilibrium constants for *n*heptane in both the methane-*n*heptane and the ethane-*n*heptane systems are considered of sufficient utility, however, to justify their presentation in Table 9. The equilibrium constants for *n*heptane, based upon ideal solutions, upon the ethane-*n*heptane system and upon the methane-*n*heptane system are presented in Figure 6. There is a fair agreement between ideal solutions and the ethane-heptane system at the lower pressures. The effect of temperature is much greater in the case of the ethane-*n*heptane system than for the methane-*n*heptane system. The marked effect of the critical pressure upon the equilibrium constants of heptane

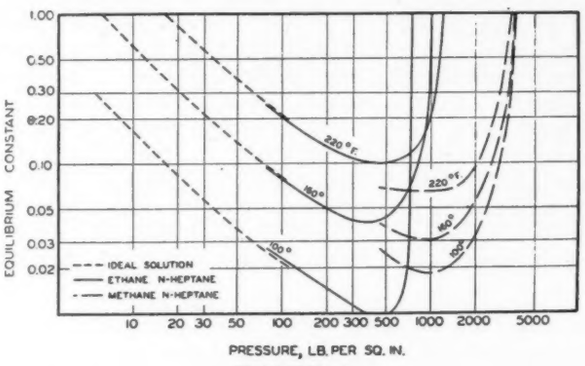


**FIGURE 6**
***Equilibrium constants for nHeptane in several hydrocarbon systems.***

in these two systems is apparent. Fig. 6 serves to illustrate the complexity of behavior which must be taken into account in any accurate correlation of the equilibrium constants of such components as *n*heptane.

## SUMMARY

The equilibrium constants presented in the foregoing tables leave much to be desired in the way of accuracy and completeness; and, as more experimental information concerning the behavior of simple and complex hydrocarbon systems accumulates, it will be necessary to modify extensively some of the values. The information for methane is reasonably complete except for the lack of a suitable correlating device to take into account the effect of aromatic components and the presence of volatile materials such as ethane. The behavior of ethane is not as well known as that for methane, but should suffice for many cases which do not digress too far from the conditions covered by the experimental work upon which the correlation is based. The constants for the heavier components are based almost entirely upon the measurements of Katz[5] at the higher pressures and upon ideal solutions at pressures in the vicinity of 1 atmosphere.

The entire correlation has neglected the effect of the relative amounts of the various components upon the equilibrium constant, because it is impossible to predict the magnitude of such an effect at the present time. It is probable, however, that appreciable uncertainties are thus introduced, especially in systems which contain a less-volatile constituent of relatively low molecular weight. The effect of the presence of the other volatile components upon the equilibrium constants of these light hydrocarbons has also been neglected. The magnitude of the effect of this neglect in an extreme case is illustrated by Figure 6, which shows the effect of methane as compared to ethane upon the equilibrium constants of *n*heptane. In this instance at least, the effect is far from negligible, and indicates need for caution in the wide use of these values until the general magnitude of such uncertainties is more firmly established.

All of the values recorded in Tables 1 to 7, inclusive, especially those for higher pressures, must be modified arbitrarily for systems which exhibit critical pressures below approximately 4000 pounds per square inch at the temperature in question. The extent of this arbitrary modification should depend

**TABLE 8**
**Equilibrium Constants for Cyclohexane**

| Pressure (Lb. per Sq. In., Absolute) | Methane-Cyclohexane System* | | |
|---|---|---|---|
| | 70° F. | 100° F. | 130° F. |
| 500 | 0.0265 | 0.0377 | 0.0530 |
| 750 | 0.0194 | 0.0282 | 0.0410 |
| 1,000 | 0.0163 | 0.0242 | 0.0360 |
| 1,500 | 0.0153 | 0.0236 | 0.0366 |
| 2,000 | 0.0175 | 0.0287 | 0.0470 |
| 2,500 | 0.0236 | 0.0394 | 0.0659 |
| 3,000 | 0.0349 | 0.0593 | 0.101 |
| 3,500 | 0.0565 | 0.0999 | 0.174 |
| 4,000 | 0.110 | 0.202 | 0.372 |

* The experimental data were for mixtures of methane, cyclohexane, and nitrogen. The system has been treated as binary, as no information was available concerning the total composition employed.

**TABLE 9**
**Equilibrium Constants for *n*Heptane**

| Pressure (Lb. per Sq. In., Absolute) | Ideal Solutions | | | | | |
|---|---|---|---|---|---|---|
| | 70° F. | 100° F. | 130° F. | 160° F. | 190° F. | 220° F. |
| 14.7 | ..... | 0.11 | 0.24 | 0.42 | 0.71 | 1.10 |
| 20 | ..... | 0.084 | 0.18 | 0.31 | 0.53 | 0.83 |
| 40 | ..... | 0.044 | 0.093 | 0.17 | 0.29 | 0.44 |
| 60 | ..... | 0.032 | 0.066 | 0.12 | 0.21 | 0.32 |
| 100 | ..... | 0.022 | 0.045 | 0.081 | 0.14 | 0.21 |
| | Ethane-*n*Heptane | | | | | |
| 100 | ..... | 0.023 | 0.044 | 0.078 | 0.127 | 0.206 |
| 150 | ..... | 0.018 | 0.034 | 0.059 | 0.095 | 0.152 |
| 200 | ..... | 0.015 | 0.029 | 0.050 | 0.081 | 0.127 |
| 300 | ..... | 0.011 | 0.024 | 0.041 | 0.069 | 0.107 |
| 400 | ..... | 0.010 | 0.023 | 0.040 | 0.066 | 0.100 |
| 500 | ..... | 0.009 | 0.025 | 0.043 | 0.068 | 0.100 |
| 750 | ..... | ..... | 0.053 | 0.073 | 0.094 | 0.117 |
| 1,000 | ..... | ..... | ..... | 0.5 | 0.2 | 0.2 |
| | Methane-*n*Heptane System* | | | | | |
| 500 | 0.0212 | 0.0247 | 0.0297 | 0.0372 | 0.0483 | ..... |
| 750 | 0.0167 | 0.0195 | 0.0240 | 0.0315 | 0.0440 | ..... |
| 1,000 | 0,0155 | 0,0183 | 0,0229 | 0.0305 | 0.0432 | ..... |
| 1,250 | 0.0158 | 0.0191 | 0.0244 | 0.0324 | 0.0450 | ..... |
| 1,500 | 0.0169 | 0.0215 | 0.0278 | 0.0368 | 0.0499 | ..... |
| 1,750 | 0.0193 | 0.0254 | 0.0335 | 0.0440 | 0.0580 | ..... |
| 2,000 | 0.0242 | 0.0318 | 0.0421 | 0.0550 | 0.0708 | ..... |
| 2,500 | 0.0476 | 0.0577 | 0.0716 | 0.0906 | 0.117 | ..... |
| 3,000 | 0.100 | 0.111 | 0.130 | 0.163 | 0.219 | ..... |
| 3,500 | 0.263 | 0.263 | 0.298 | 0.383 | 0.557 | ..... |

* The experimental data were for mixtures of methane, *n*heptane, and nitrogen. The system has been treated as binary, as no information was available concerning the total composition employed.

**TABLE 10**

**Comparison of Calculated and Experimental Bubble-Point Pressures, Sub-surface Sample**

**Analysis**

(Expressed as mole percent)

| | |
|---|---|
| Methane | 32.23 |
| Ethane | 4.24 |
| Propane | 3.35 |
| *Iso*butane | 1.08 |
| *n*Butane | 1.48 |
| Pentanes | 2.18 |
| Heavier* | 55.44 |

**Bubble-Point Pressures**

| | 100° F. | 160° F. | 220° F. |
|---|---|---|---|
| Calculated | 1,730† | 1,900 | 1,930 |
| Observed | 1,643 | 1,881 | 2,025 |

* Average molecular weight of heavier material, 172. This material was assumed to have a viscosity-gravity factor of 0.82 on the basis of the viscosity-gravity factor of other samples of material taken from the same field.

† Expressed as pounds per square inch, absolute.

upon the magnitude of the critical pressure. The importance of this is well illustrated in the case of the constants for *n*heptane in the methane-*n*heptane and in the ethane-*n*heptane systems, as indicated in Figure 6.

In general, the individual experimental data agreed with the correlations presented here with a maximum discrepancy of approximately 3 percent, except in a few isolated cases in experimentally difficult regions. The prediction of the critical states of complex hydrocarbon mixtures is uncertain at the present time. The utilization of data concerning the critical behavior of binary systems as a basis for such prediction is open to question, and is only proposed as a temporary index of the behavior to be expected until pertinent experimental information in this connection is available.

## APPLICABILITY OF DATA

It is impossible to state the accuracy with which the equilibrium constants submitted in this paper apply to naturally-occurring hydrocarbon systems in general. However, in specific instances the accuracy of prediction may be checked directly against experimentally-determined behavior. One of the more sensitive tests in this regard is the prediction of bubble-point pressures from a knowledge of the composition of the system in question.

In an earlier publication[25] the authors submitted volumetric data concerning the behavior of a sub-surface liquid sample obtained from the Conroe Field. Along with these data were included a fractionation analysis of the sub-surface sample, which is reproduced in Table 10. From this information, and from the equilibrium constants for the components from methane through the pentanes, the bubble-point pressure may be calculated by the trial solution of the following equation in which $K_1 \ldots K_n$ and $n_1 \ldots n_n$ are the equilibrium constants and the mole fractions of components 1 to $n$ respectively.

$$K_1 n_1 + K_2 n_2 + \ldots + K_n n_n = 1 \quad \ldots\ldots\ldots (3)$$

The results of the solution of equation (3) are given in the latter part of Table 10, along with the corresponding experimentally-determined values. The agreement is within about 5 percent at 100 and 220° F., but fortuitously the agreement is within 1 percent at 200°F.

A similar disagreement was found between the predicted and experimental behavior of mixtures of methane and a crude oil[26] which were presented in an earlier publication.[18] Such discrepancies indicate appreciable uncertainty in the values of equilibrium constants at the higher pressures recorded in Table 1. This uncertainty cannot be cleared up until more experimental work concerning the behavior of methane in a number of simple and complex hydrocarbon systems has been completed for these pressures and temperatures.

This single illustration is not considered to be generally indicative of the applicability of the equilibrium constants presented here. Their utility in engineering practice can only be determined by their use in the solution of some of the problems encountered by the petroleum technologists. The practical value of the results obtained will indicate whether or not the use of such approximate methods of predicting the phase behavior of naturally-occurring hydrocarbon mixtures is justified. In the meantime, it is hoped that more experimental results of a pertinent nature will continue to appear, and thus aid in the more precise evaluation of equilibrium constants.

## ACKNOWLEDGMENTS

This work has been carried out as a part of a general program of study of the volumetric and phase behavior of naturally-occurring hydrocarbon mixtures, which forms a part of the activities of Research Project 37 of the American Petroleum Institute. The authors wish to express their appreciation for the financial aid and cooperation of this Institute—which have contributed greatly to the progress of this work. The kindness of Prof. E. H. Boomer and Mr. W. B. Kay, in making available to the authors certain data before their publication, is appreciated.

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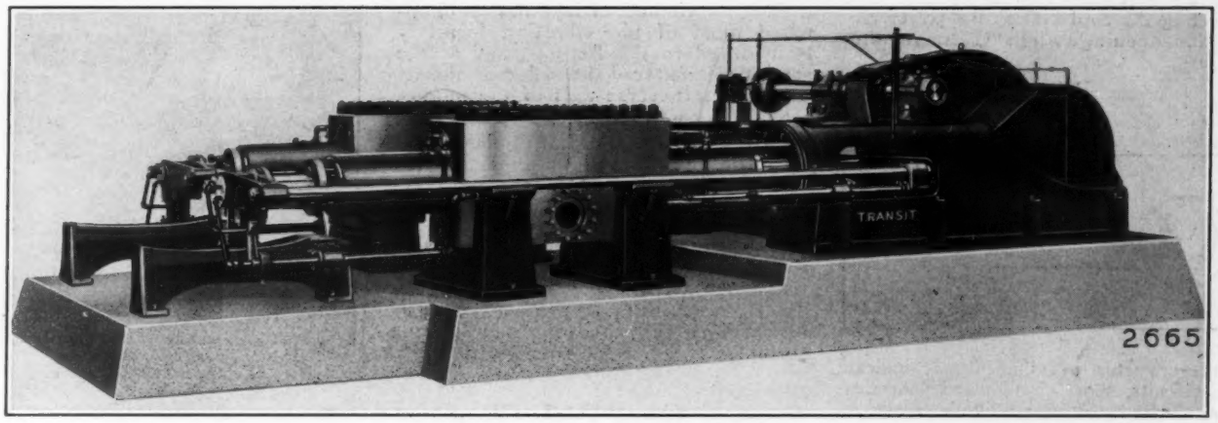
# TRANSIT

## POWER DRIVEN HOT OIL PUMPS

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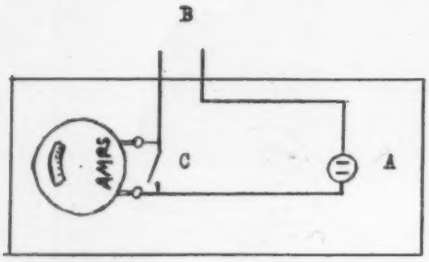
# IDEAS to help plant efficiency . . .

## Circuit Tester for Lab Appliances

THE sketch shows a simple arrangement of ammeter, shunt switch to protect ammeter, plug-in receptacle, and extension cord for connection to power circuit. By plugging the hotplate, rheostat heater or other appliance into receptacle "A", connecting the cord "B" to the power circuit and opening switch "C" the reading




on the ammeter will immediately indicate open circuits, short circuits and poor contacts. Such tests can readily be made by any laboratory technician thus saving the time required to wait for a regular electrician.

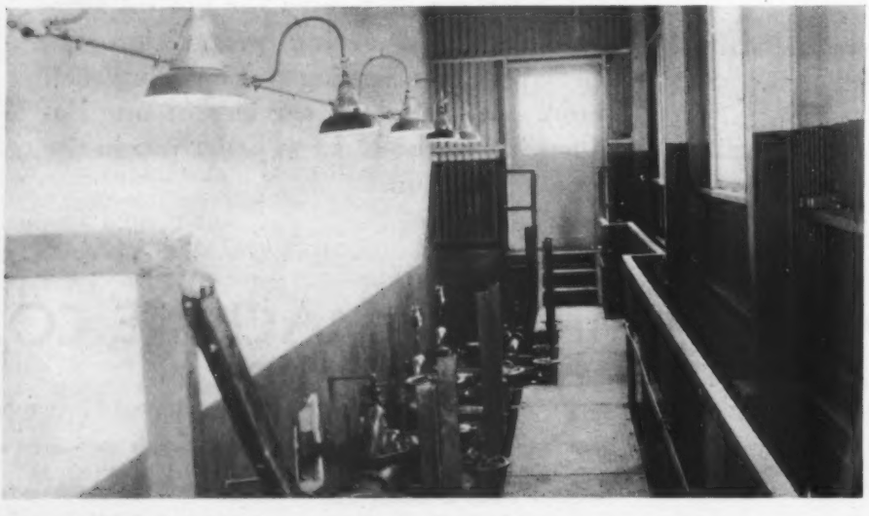
*Olean, N. Y.* G.F.F.

## Improving Visibility in Transfer Pump Room

TWO changes in the building housing a battery of transfer pumps handling gasoline and other light products each contributed to improving light—and consequently, maintenance—conditions within the structure.

The light fixtures were moved from their former location just below the room trusses and bracketed on the firewall separating the motors from the pumps. Further accurate spotting of the illumination where most desired was secured by using wide-sweep gooseneck bends for each fixture, supporting the loop near its top with a wire carried to a screw higher on the wall. This method of installation eliminated most of the vibration formerly transmitted to the fixtures, and at the same time centered the reflector closely over the transverse axis of the pumps.

The second improvement involved the carrying downward of the light wall paint on the firewall to a height just above ordinary hand contact when servicing the pumps. This extended white wall served as reflector to improve light conditions under the crosswalk, and also to increase the intensity on the pumps themselves, rendering still easier the detection of leaks or mechanical troubles before they had time to become serious.



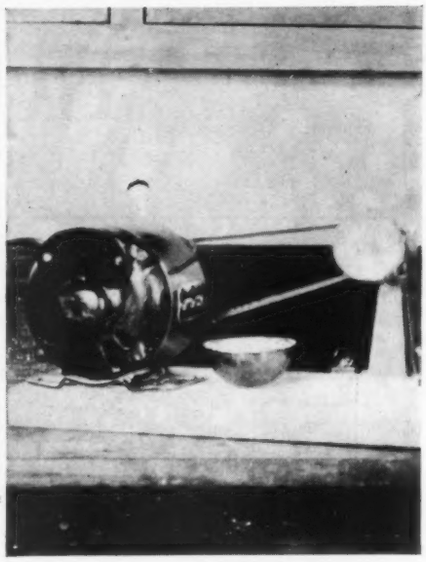
***Relocated light fixtures and extended white section of wall paint insure thorough inspection of this transfer pump battery and simplify any maintenance thereon.***

## Copper Gum Dish Cleaner And Polisher

AFTER a gum test has been run on a sample of gasoline, it is sometimes a tedious task to remove the baked residue and polish the utensil for another run. Chemists at McMurray Refining Company's Tyler, Texas, plant, have made this task a more pleasant one by the use of an apparatus designed in the laboratory, and assembled from standard equipment which may be obtained from any electrical or wood working store.

The equipment consists of a quarter-horsepower electric motor, with service cord, a polishing head and cloth buffing wheel, a connecting belt and wood base. The motor and polishing head are mounted on a piece of 2 x 8, about 18 inches in length, with the motor at one end and the polishing head near the center. Both are fastened to the base with small bolts, allowing sufficient room when boring holes for the motor to adjust the tension of the belt.

When operating the polisher, the service plug is attached to an outlet in the wall of the laboratory, and when the speed of the polishing head is sufficient, the gum dish is held against the buffing wheel and given a slightly rotating motion with the hand, and in a short time, all caked gum is removed and the dish given a polish that is secured otherwise with much labor.



***Copper Dish Cleaner***

## Chain Hoist "A" Frame Used in Engine Room

IN order to more efficiently handle heavy cylinder heads, liners and pistons when making repairs on compressor engines in its Rodessa gasoline plant, Coltexo Gasoline Corporation has made a movable hoist frame which is easily moved over the engine room concrete floor and slips easily between the firing or compressor cylinders of the twin four-cycle engines. When making up this hoist, heavy tubing was used for the standards and cross members instead of ordinary 2-inch piping. Each end of the hoist frame was made as an "A" frame and connected to each other at the top with a single length of 2-inch tubing. Bracing was obtained by welding cross members near the lower end and near the top of each end

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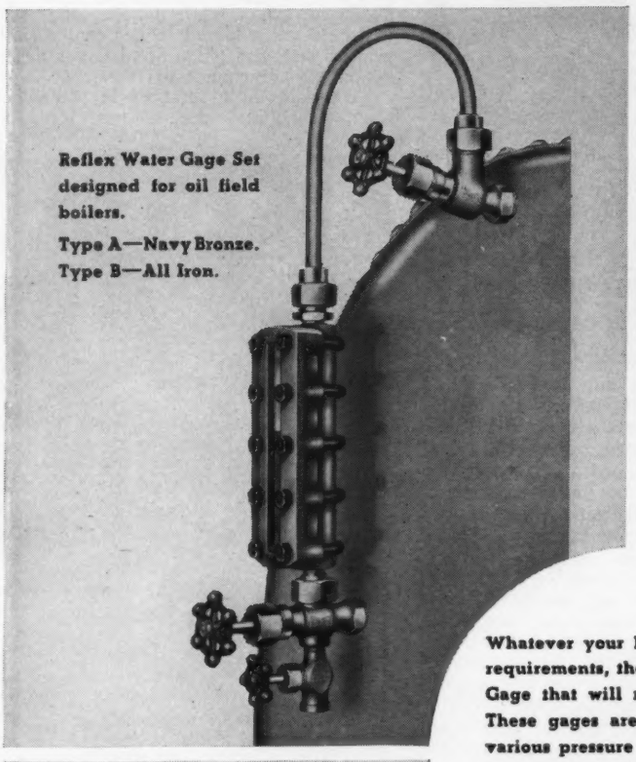

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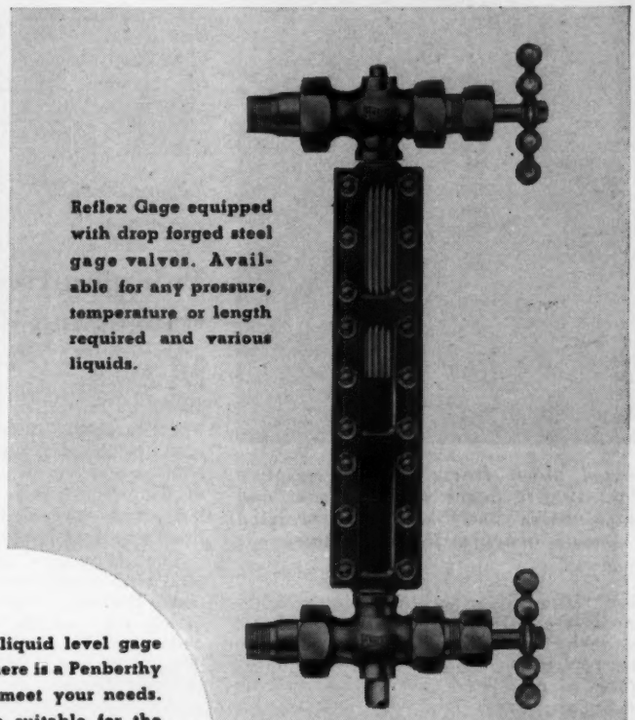

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**Navy Type Gage**
**Extra Heavy Bronze**

**All Iron Gage**
**Extra Heavy**

## PENBERTHY INJECTOR COMPANY

**Manufacturers of QUALITY PRODUCTS Since 1886**
**DETROIT, MICH. • Canadian Plant, Windsor, Ont.**

***Geared block frame used in gasoline plant to lift heavy engine parts, and which lends itself as an improvised work bench at the same time.***

piece. In addition to this bracing, additional strength was built into the hoist frame by welding diagonal pipes from the top cross member to each short brace in each end piece. To assist in supporting the load, uprights were placed between the lower cross member and the diagonal bracing. A heavy service connection was welded to the main cross member connecting each end so that the hook of the spur geared block could be placed in position for use. The entire unit was mounted upon ball bearing casters which makes it easy for a repairman to move it about the engine room. The distance between the legs of the end frames and the center support is such that an oak two by twelve may be laid lengthwise for an improvised work bench, or platform upon which to place heads and liners for inspection.

## Handy Holder for Fuse Panel Gloves

MAINTAINING a pair of insulated gloves for the changing of fuses in the main panel serving the lights and auxiliary low-voltage motors about its plant, one refinery made it easy to keep the gloves at the proper spot by affixing an ordinary spring clothespin to the wall adjacent to the panel enclosure, just below the switch controlling the emergency lighting fixture providing illumination—from a storage battery—in case of total darkness within the plant.

Due to the probability of the employee making the fuse change having crude or some semi-refined petroleum on his hands, rubber gloves are not used for this service, but instead a pair of heavy asbestos gloves, on a canvas foundation, are provided.

Placing the glove holder outside the fuse enclosure makes it easy to check their being "on the job," and acts as a reminder to the man making the replacement to again hang the gloves up, instead of jamming them into a pocket or throwing them down anywhere.

*Kilgore, Texas.* CHARLES C. LYNDE.

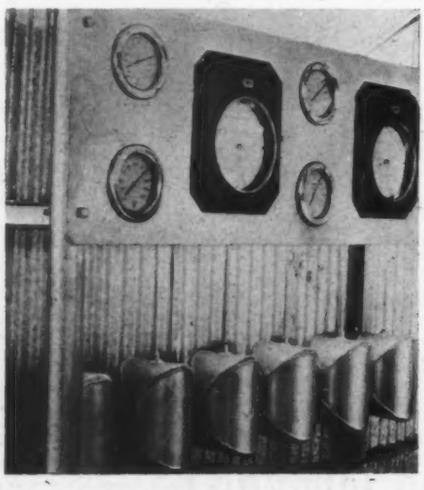
***Panel Glove Holder***

## Pulsation Dampener on Gauges and Recorders

MANY gadgets are used to dampen the pulsation of gas flow in headers and discharge lines used in compressor stations where accurate records are desired. Phillips Petroleum Company, Edmond, Oklahoma, employees designed a particular type of dampener that is not only inexpensive, but permits a recorder on the gas line to draw a uniformly narrow line on the charts.

The dampeners are made of six-inch pipe, with orange-peel heads welded in both ends, the length of each being approximately eight inches, and with quarter-inch collars welded in the center of each head. The gauge line is brought from the header carrying the gas in the usual manner, but with the dampener placed between the header and the instrument, whether it be a recorder or a simple indicating pressure gauge.

Observing the operation of these instruments, the lines drawn on the charts are usually fine, with almost imperceptible variations. No needle valves are used between the headers and the gauges, except to close the line from the instrument when changing pressure elements, or repairing the recorders and indicators. It is not necessary to restrict the line with a pinched gate to obtain a dampened action of the Bourdon springs, which in many cases when so used, causes a false record to be obtained.

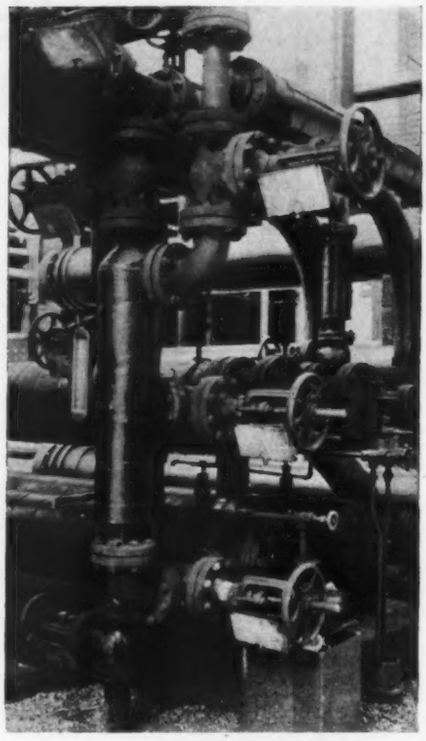


***Pulsation Dampeners***

## Oil Drip Catchers

UNITED Refining Company, Warren, Pennsylvania, prevents small oil leaks from staining insulation and forming dark spots on chatted areas around exchangers and the like, by attaching especially designed buckets beneath each gate valve packing gland. The oil catchers are in the shape of small troughs, varying size according to the service required of them, with ends made in the form of an equilateral triangle. The plant mechanic makes them in the tin shop, with quarter-inch galvanized collars soldered in the center of the peaked part, and plugs fitted finger tight to retain the oil caught in them.

To retain these catchers in place, holes are punched in both sides near the top at each end with wire bails snapped in place when placing them on the gates for service. These receptacles are periodically emptied, usually by removing the plug while holding a larger container beneath them to catch the accumulated oil. They are relatively inexpensive, and go a long way toward helping to keep a plant clean.



***Oil Drip Pans***

## Wrench Board Used by Stillmen Only

WHEN an operator of a cracking plant needs a tool, he needs it right now, and following this idea through, a complete set of pipe wrenches, hammer, chisel, pliers and adjustable end wrenches was placed near the control room of McMurrey Petroleum Corporation's new Dubbs unit at Tyler, Texas. This board is sacred to the stillmen, and no other employee is supposed to as much as cast a covetous eye in that direction. Not only do the stillmen jealously guard the tools on this board, but dire consequences will occur if one is missing, no matter who is at fault. The board is made of sheet steel, salvaged from tank

# Guard LIFE and PROPERTY...

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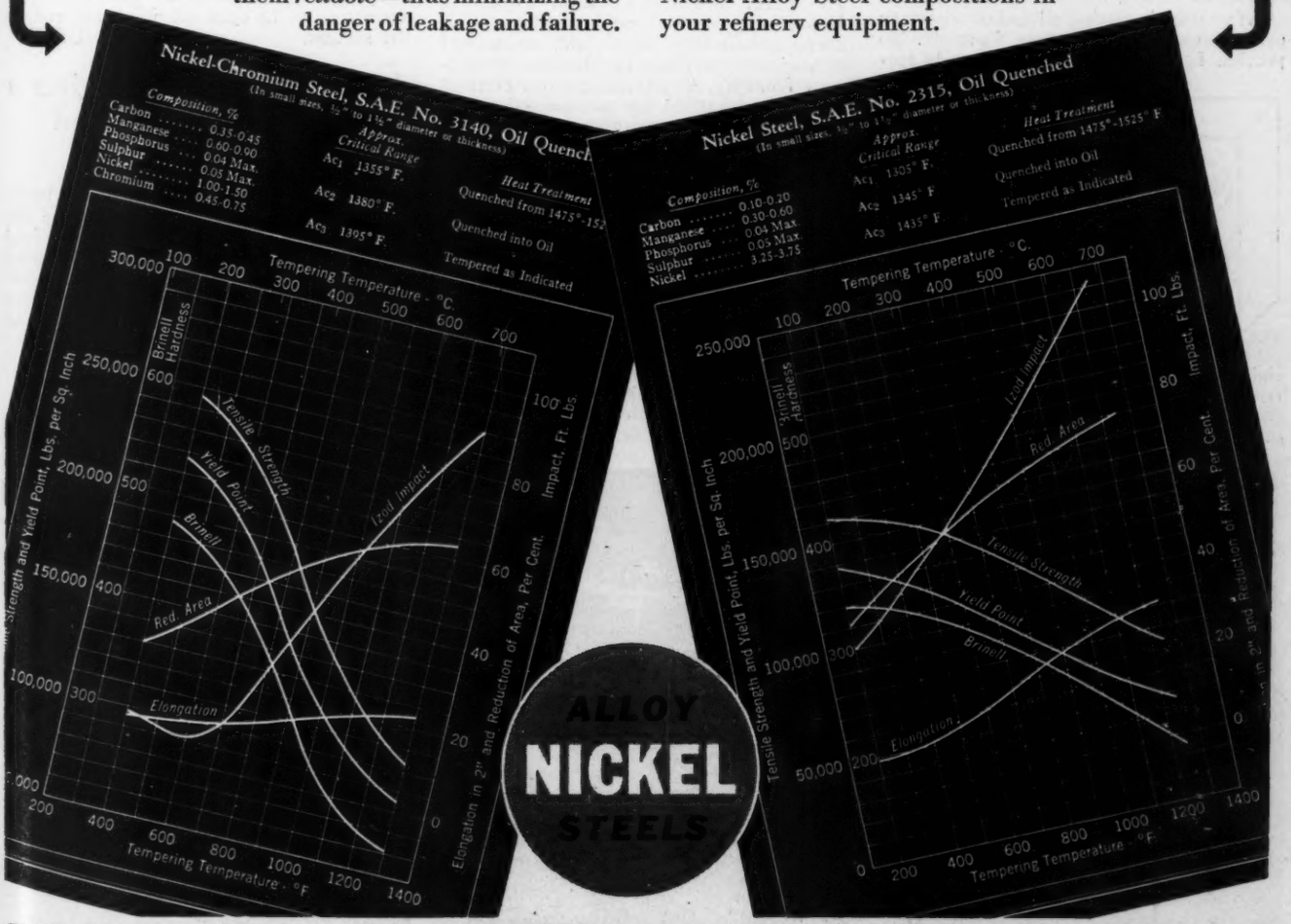
## FOR HIGH TEMPERATURE SERVICE

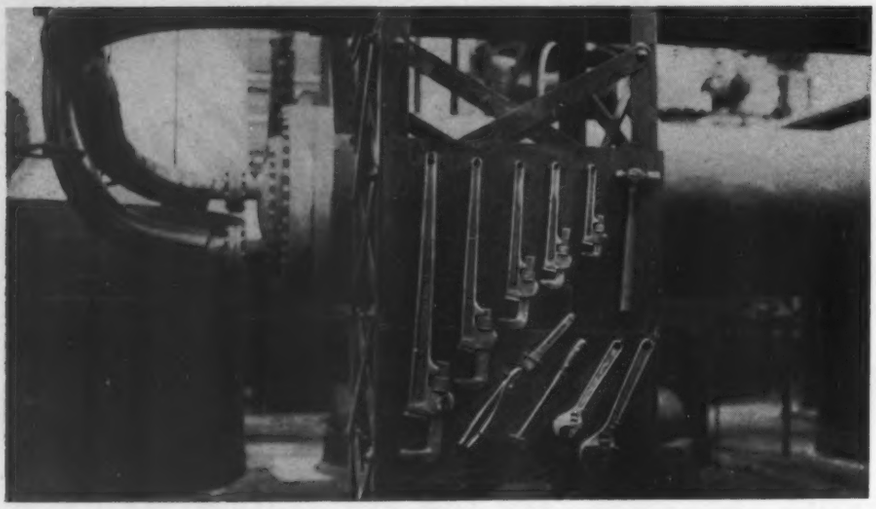
When refinery lines are running at 900° F. to 1200° F. leakage or failure of a pipe joint may be the forerunner of disaster. Hence, refinery bolts must be made of dependable materials—capable of withstanding the mechanical stresses of tightening up as well as the additional thermal and pressure stresses encountered when the lines are running hot in operation. Nickel Alloy Steels are used for this vital application because their high yield strengths and toughness make them *reliable*—thus minimizing the danger of leakage and failure.

## FOR LOW TEMPERATURE SERVICE

The use of subzero temperatures in refining operations requires materials which stay tough in extremely cold zones. Bolts of Nickel Alloy Steel resist low temperature embrittlement and provide the requisite physical properties. • • The accompanying charts give the mechanical properties of two Nickel Alloy Steel compositions which are especially suitable for refinery bolts, used in high and low temperature service. We invite consultation on the use of these and other Nickel Alloy Steel compositions in your refinery equipment.




**THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.**

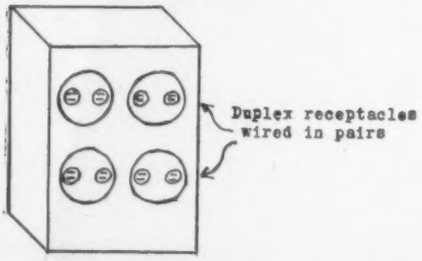


*Tool board installed in yard of refinery, used exclusively by operators when adjustments are to be made.*

bottoms, mounted on supporting structure which carry piping, and provided with adequate hooks to support the wrenches selected to hang there. It is fireproof, and out of the way, yet easy to get to when tools are needed.

## "Appliance Outlets for Test Table"

THE increasing number of electrical devices used in testing oil makes necessary many more receptacles than formerly. To provide for present and future needs special boxes were made with four duplex receptacles on each side. Each pair of receptacles was separately fused to prevent overloads. One such box was mounted at each end of a ten-foot double work table thus accommodating six electrically heated viscosimeters and the necessary hot plates and timers. The lower row of receptacles was set high enough so that the extension cords would not be dragging on the table.




*Olean, N. Y.* G.F.F.

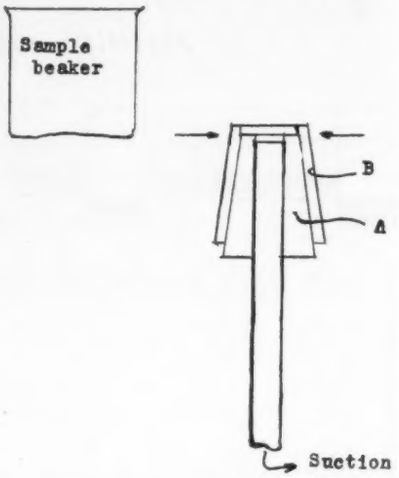
## Water Drip Pans

IN THE new units which Pure Oil Company constructed during 1937, many steam lines were laid, connected to various processes and heaters to prevent freezing. Condensate from control valves is handled by galvanized catch basins, placed at advantageously selected points above vessels, to prevent discoloration of the paint sprayed on these units. The pans were made of galvanized sheet metal, shaped in the form of a small bread pan, and supported beneath the drips with wire bails. Small diameter piping was connected to the bottom of each pan and led to a common funnel drain beside each vessel. When it is necessary to bleed condensate from dead end steam lines, the pans beneath the connections are used to remove the water, and keep the surfaces of the equipment clean and free from stains.

*Water Drip Pans*

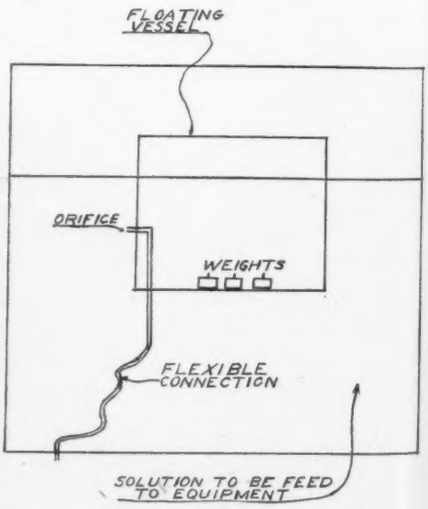
## Suction Fitting for Filling Ostwald Pipettes

A VERY convenient arrangement for charging oil to Ostwald pipettes is shown in the sketch. Copper tubing is brought to a convenient level where a support is provided for the sample beaker. The fitting used on the working end of the suction line is made of a one-hole No. 0 rubber stopper "A," a short piece of ½-inch rubber tubing "B" which projects just enough above the stopper to insure centering the pipette. The speed of filling is easily controlled by pinching as shown by the arrows so as to open the joint and reduce the suction. G.F.F.




## Apparatus for Supplying a Constant Supply of Feed To Equipment

THIS apparatus was designed to make use of a constant static head above the orifice to supply a constant amount of feed to the equipment. The volume can be varied to the desired amount by changing the size of the orifice or by changing the amount of weights that are carried in the floating vessel.




The size of the apparatus may be varied to suit the need. It may be used in commercial equipment or for supplying very small amounts of solution in a laboratory set-up.

*Arkansas City, Kansas.* W.N.E.

## Delbridge Elected President A.S.T.M.

DR. T. G. DELBRIDGE, Manager, Research and Development Department, The Atlantic Refining Company, Philadelphia, was elected president of the American Society for Testing Materials, at its recent annual meeting held in Atlantic City.

A native of Batavia, New York, where his early public school education was obtained, Doctor Delbridge later was graduated with an A.B. degree from Union College in Schenectady. He specialized in Greek, Latin, and chemistry and was elected to Phi Beta Kappa and Sigma Xi. In 1907 he obtained his Ph.D. from Cornell University where he was an instructor in chemistry from 1904 to 1909. He became chemist for The Atlantic Refining Company in 1909 and in 1914 was assistant superintendent; in 1918, chief chemist; in 1922 assistant plant manager; and in 1923 became manager, Research and Development Department, the position he now occupies.

While the research activities under his supervision have embraced a wide field of petroleum investigation, he has contributed especially to developments in distillation methods, solvent refining (the nitrobenzene process), wax manufacturing and methods of testing.

Doctor Delbridge was a member of the A.S.T.M. Executive Committee, 1923-1925, and is completing a term as A.S.T.M. vice president. He has been vice chairman of Committee D-2 on Petroleum Products and Lubricants since 1930. He served two terms as a member of the society's Committee E-6 on Papers and Publications and also for six years was a member of the important Committee E-10 on Standards. He is one of the representatives of the society on the Sectional Committee on Petroleum Products and Lubricants and on the Sectional Committee on Valid Certification.

He is a member of the American Chemical Society, Franklin Institute, American Petroleum Institute, and the British Institution of Petroleum Technologists. He has written extensively on petroleum refining subjects and contributed the chapter on testing methods in Day's Handbook of the Petroleum Industry. Doctor Delbridge's hobby is radio.

T. G. DELBRIDGE

# The Look Box

## Lowe Reelected by Natural Gasoline Men

THE board of directors of the Natural Gasoline Association of America recently re-elected William F. Lowe as secretary-treasurer of the association. This will be his fifth term in that office.

The association has just completed a particularly successful and busy year, according to J. A. LaFortune, Warren Petroleum Corporation, president of the association, and plans for the coming year indicate a continuation of that trend. Committee activities already scheduled are of widespread interest and will require considerable work of research nature to bring the desired conclusions. A series of field tests to determine the relative merits of new gas gravity instruments as compared with the widely used gravity balance is to be started by the Gas Testing Committee in the near future while the Technical Committee is undertaking the study of gas sampling and gas analysis methods as well as several other research projects. The Gas Contract Committee has an unusually active agenda. Close contacts with other technical societies such as the American Society for Testing Materials and Society of Automotive Engineers are to be maintained.

J. W. Vaiden, chairman of the 1938 Convention Program Committee reports that the May meeting was particularly satisfactory both from the standpoint of attendance and the volume of work done. The committee was particularly gratified with the increasing interest of field men in the "Kinks" session which has grown in importance steadily in the three years of its existence. Plans are now being made to give this group a larger place on the program and to increase the prizes offered for the operating ideas presented.

### Conventions

| | |
|---|---|
| SEPT. 5–9 | American Chemical Society, Milwaukee, Wisconsin. |
| 14–16 | National Petroleum Association, Hotel Traymore, Atlantic City, N. J. |
| OCT. 6–7 | Society of Automotive Engineers, National Regional Fuels & Lubricants Meeting, Tulsa, Oklahoma. |
| 19–21 | Independent Petroleum Association, of America, Tulsa, Oklahoma. |
| NOV. 14–18 | American Petroleum Institute, Stevens Hotel, Chicago. |

## Pennsylvania Grade Speakers Review Progress

Reviewing fifteen years of the accomplishments of the Pennsylvania Grade Crude Oil Association, W. F. Clinger of Warren, its president, told the membership at the annual meeting in Pittsburgh that only cooperative action pulled the oil industry out of its troubles in the past and concerted action could repeat the process.

Clinger said that the Pennsylvania oil business was in much worse condition 15 years ago than it is now and that out of those desperate conditions the association was born. Depressed conditions now, traceable to the economic situation the country over, can only be improved by tactics similar to those employed in the early 1920's, he said, when producers and refiners recognized the seriousness of the situation and worked out a program which proved to be the salvation of the Pennsylvania oil industry.

Consistent advertising and intelligent cooperation have been mainly responsible for the achievements of the Pennsylvania Grade Crude Oil Association, according to Charles Coolidge Parlin of Curtis Publishing Company, Philadelphia, another speaker on the afternoon program.

"In 1923 you weren't sure whether advertising could popularize your oils sufficiently to regain your old markets," he said. "You weren't sure that

W. F. LOWE

a large group of refiners and producers with diverse interests could hold together. But you started and as a result you have set up a unique record among trade associations."

Parlin said that nothing has happened to necessitate a change in the formula. "As an advertiser you are not talking to a standing army. You are talking to a parade. It is a moving market and you can't stand still and keep up with it."

Dr. F. L. Carnahan, of Pennsylvania State College, State College, another speaker, declared that the unique and well-recognized properties of Pennsylvania grade motor oil have their origin in the chemical composition of the crude. Examination of small fractions of Pennsylvania oils which have been taken apart by instruments designed and built in the college laboratory demonstrates that the high paraffinicity of the crude oil from the region is the source of the high viscosity index, high boiling points, high gravities and high flash and fire tests of the motor oil made from it.

"It is thus evident," said Dr. Carnahan, "that the more thoroughly Pennsylvania oils are investigated the more they justify our faith in them. When special oils are needed for purposes regarded today as unusual, Pennsylvania grade crude can furnish them."

## Plan Large Oil Display At New York Fair

PETROLEUM'S contributions to human progress and its significance for "The World of Tomorrow" will be dramatized by the Petroleum Industry Exhibition, Inc., at the New York World's Fair, 1939, it was announced by T. H. Taylor, president. The exhibit, which will be located at the entrance of the Plaza of Light in the Blue Section of the Fair, will cover an area of 64,899 square feet, comprising one of the largest of the industrial displays.

A spectacular feature of the exhibit will be an oil derrick. Manned by living workers and with the most modern equipment, the process of drilling for oil will be demonstrated.

Another unusual feature of the exhibit will be an animated relief map of the United States, southern Canada and northern Mexico on which miniature oil derricks will graphically demonstrate the origin and expansion of the industry. Bodies of water coursing through and around the map will trace the principal rivers of the United States and the oceans surrounding it. The map will be in the Petroleum Garden, where modern refining processes will also be demonstrated by an animated model of a refinery.

Work has started on the Petroleum Building, which will be an equilateral triangle in design and cover an area of 28,166 square feet. Measuring 200 feet on each side and 80 feet high, the building will be constructed of metal to catch the rays of the sun in the daytime and the brilliance of indirect lighting at night.

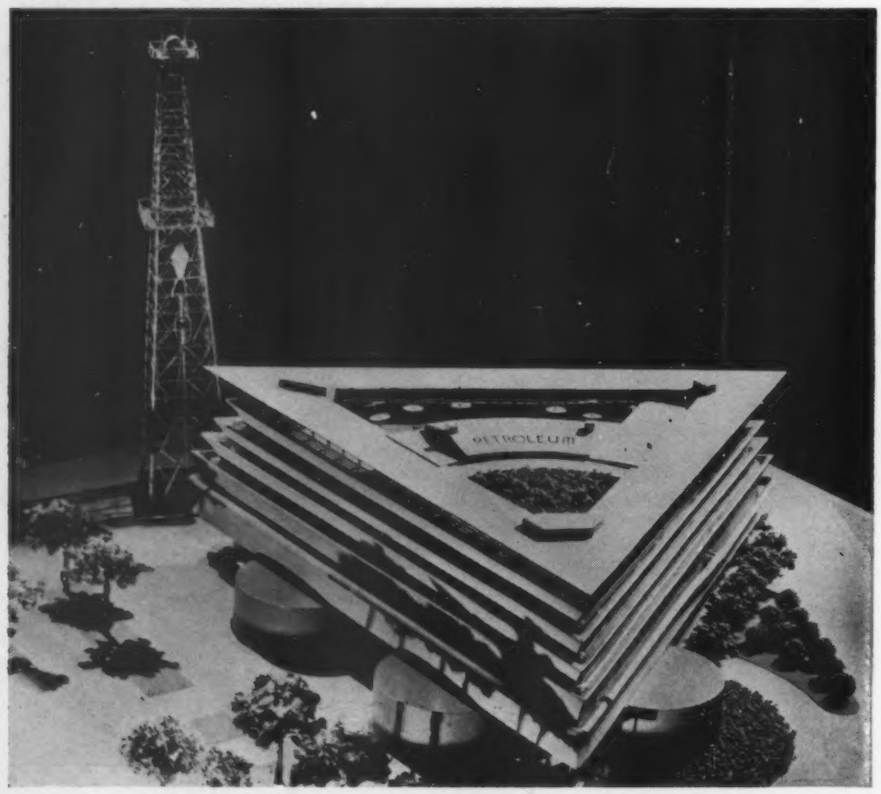
The exterior walls of the building will be in three shades of blue and will be constructed to form four flaring tiers, suggesting the shape of a cooling tower. The lighting effects will be achieved by the use of fluorescent tubing, each tier being lighted by the tier below it.

Instead of being built on the ground, the Petroleum Building will be chiefly supported by four huge reproductions of oil tanks, 20 feet high. Within the tanks will be exhibits, designed by Gilbert Rohde, showing how petroleum has revolutionized transportation and how the industry's constant scientific development has advanced agricultural and industrial expansion and resulted in making possible a large number of the modern comforts in the home.

The interior of the building, to be known as the Great Hall of the Industry, will have rows of seats to enable visitors to view a spectacular show which will be presented on the mammoth stage occupying the apex of the Great Hall. The show, which will dramatize the discovery and development of petroleum, will employ new techniques in its production and will mark an interesting advance in theatrical entertainment.

The Petroleum Building will be open on all sides, permitting a complete circulation of air as well as access from any part of the grounds. Wide exterior macadam walks surrounding the building will merge into it without interruption.

Architects for the Petroleum Building are Voorhees, Gmolin & Walker. The companies participating in the Petroleum Industry Exhibition are The American Oil Company, The Atlantic Refining Company, Cities Service Oil Company, Gulf Oil Corporation, The Pure Oil Company, Richfield Oil Corporation of New York, Shell Union Oil Corporation, Sinclair Refining Company, Socony Vacuum Oil Company, Inc., Standard Oil Company of New Jersey, Sun Oil Company, The Texas Company, Tide Water Associated Oil Company, and Phillips Petroleum Company.

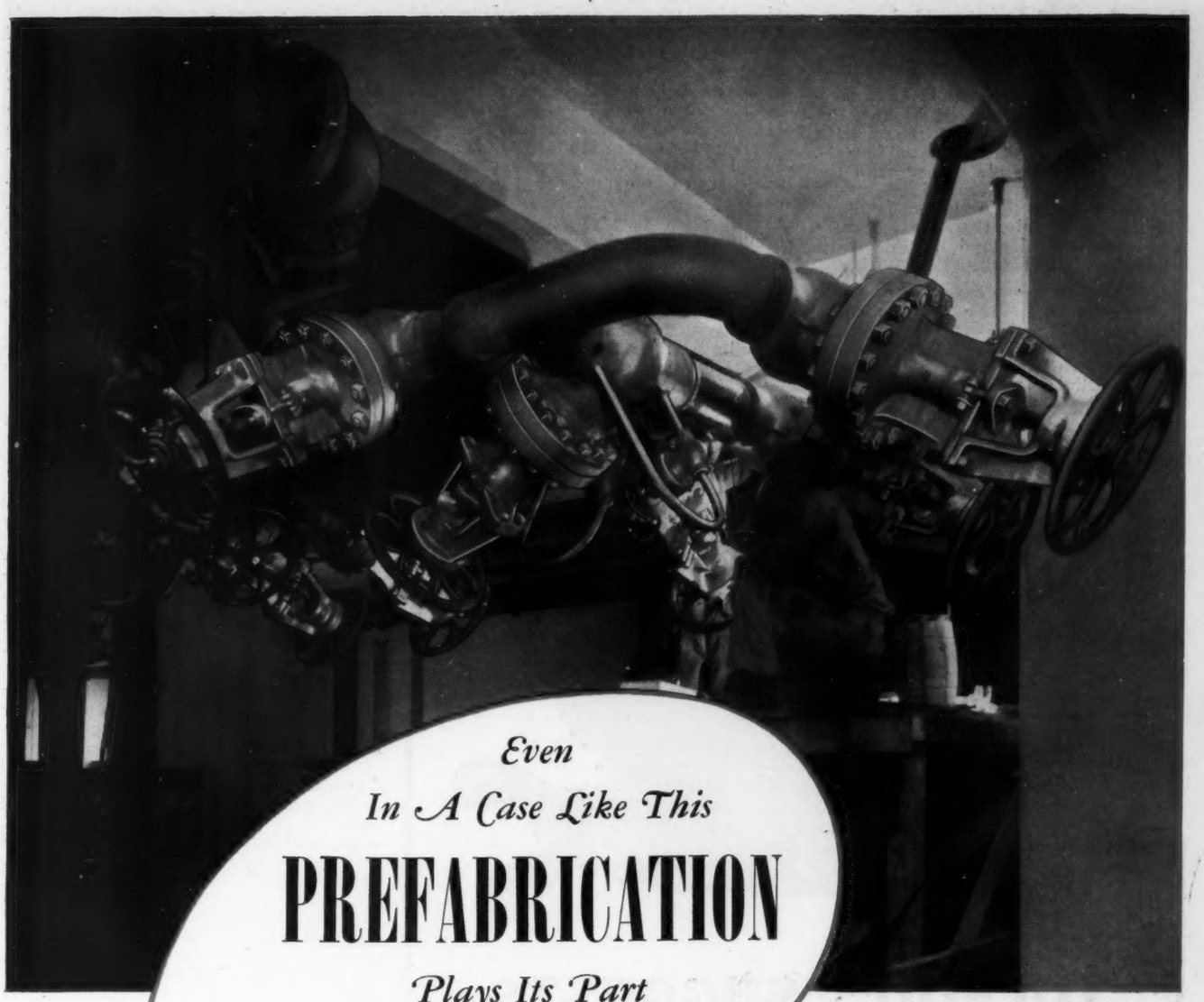


***A brilliant triangle of gleaming blue metal supported 20 feet above the ground by four huge replicas of oil tanks will house the petroleum industry exhibit at the New York World's Fair 1939, as indicated by the accompanying model. Dramatic and spectacular exhibits will show how research in petroleum has aided human progress. A unique feature is the derrick in back which, manned by living workers, will demonstrate the process of drilling for oil.***

## Linhoff New President California Association

MEMBERS of the California Natural Gasoline Association have elected H. R. Linhoff of Richfield Oil Corporation to the presidency of the association, succeeding J. C. Burks of O. C. Field Gasoline Corporation who has served during the past year. P. S. Magruder, General Petroleum Corporation, was elected vice president. Both men have been prominent in the affairs of the association for many years. Linhoff is manager of the natural gasoline division for Richfield Oil Corporation and has been with that company in various capacities since 1925. Magruder is assistant manager of the gas department for General Petroleum Corporation and has been with that company for 13 years. The association has carried on the cooperative study of many types of problems with which the gasoline industry is concerned since its formation, December, 1925.

The association meets monthly and has achieved an enviable position in the industry and an increasing prestige among other technical groups.



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*In A Case Like This*

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The compactness that locates this group of big gate valves close together can be provided in only one way . . . by carefully engineered, prefabricated sub-assemblies, welded into a finished unit.

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## Forecast of Demand for Oil, July, 1938

THE daily average supply of domestic crude oil estimated by the Bureau of Mines to meet the market demand in July 1938 is 3,398,100 barrels. This is 64,800 barrels higher than the estimate for June, 1938, 173,500 barrels (5 percent) less than the actual daily production for July, 1937, and 5 percent less than the demand for domestic crude for that month.

*Current situation.* Daily average crude-oil production and runs to stills during the four weeks, May 7 to June 4, averaged about 3,200,000 and 3,170,000 barrels, respectively. During this period refinable stocks declined 7,482,000 barrels, 87,000 of which was in foreign stocks and 7,395,000 barrels in domestic grades. The addition of this amount to production gives 3,465,000 barrels as the apparent daily average demand for domestic crude oil. The excess over the May estimate of the Bureau may be attributed to runs to stills of about 50,000 barrels daily greater than was forecast, to unexpectedly large crude exports, transfers, losses, and to a probable increase in stocks of heavy crude in California.

### Motor Fuel

*Domestic demand.* The estimate for domestic motor-fuel demand for July 1938 is 49,930,000 barrels, or 1.5 per cent lower than the actual demand for July 1937.

*Stocks.* Stocks of finished and unfinished gasoline amounted to 90,059,000 barrels on April 30. According to statistics of the American Petroleum Institute, these stocks declined 3,500,000 barrels during May, bringing them to approximately 86,500,000 barrels as of May 31. The Bureau estimates that finished gasoline stocks will decline 6,600,000 barrels during July.

*Gasoline production.* Benzol and "direct" sales and losses of natural gasoline have been estimated as 900,000 barrels, making the estimated refinery production of gasoline 46,430,000 barrels. This is distributed among the various districts as follows (thousands of barrels): East Coast, 6510; Appalachian, 1610; Indiana-Illinois, 8310; Oklahoma, 2250; Kansas-Missouri, 2510; Inland Texas, 3740; Texas Gulf Coast, 11,830; Louisiana Gulf Coast, 1450; North Louisiana-Arkansas 960; Rocky Mountain, 1150; California, 6110.

### Crude Petroleum

*Runs to stills.* During the first four months of 1937 natural gasoline blended at refineries constituted 7.0 percent of the total refinery production of gasoline, compared with 6.2 percent for the same period in 1937. Moreover, the proportion of natural gasoline during the summer of 1937 was distinctly higher than that for 1936, indicating an upward trend in refinery utilization. The Bureau is therefore estimating the proportion of natural gasoline for July 1938 as 7.0 percent, compared with 6.2 percent in July 1937. On refinery production this amounts to 3,250,000 barrels.

The yield of straight-run and cracked gasoline is estimated as 44.00 percent, compared with actual yield of 43.22 percent in July 1937 and 44.56 percent in July 1936. The application of the current yield to the estimated straight-run and cracked gasoline production of 43,180,000 barrels gives refinery crude-oil requirements as 98,140,000 barrels, or 3,165,800 barrels daily.

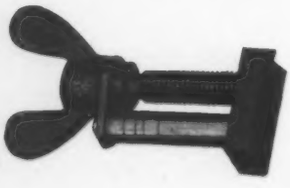
*Foreign crude runs.* Foreign crude runs to stills are estimated at 2,400,000 barrels, 200,000 barrels more than the June estimate.

*Exports, fuel, and losses.* The estimate for crude-oil exports has been increased 1,100,000 barrels over the June estimate to 7,100,000 barrels.

"TOLEDO" SUGGESTS—

a "TOLEDO" No. 1BR for threading satisfaction on 1 to 2 inch pipe.

No bushings. Long-life pipe holder. Three broad-faced jaws with size-marked guide bars operated by large wing-head set screws make for easy, accurate centering.



Separate set of dies for each size—assuring easy cutting and smooth, accurate threads.

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"TOLEDO"


## New A.S.T.M. Fuel Oil Specifications

THE American Society for Testing Materials has recently issued revised tentative specifications for fuel oils and also a new tentative method of test for sediment in fuel oil by extraction. These new standards were approved by the Society's Committee on Standards on the recommendation of Committee D-2 on Petroleum Products and Lubricants. The test method for sediment has been designated D473-38 T and the fuel oil standards continued as D 396 with a change in the year, the complete designation being D 396-38 T.

*Fuel Oil Specifications:*

The specifications for fuel oil were issued for the first time as tentative in 1934. Since then a number of suggestions for improvements have been received and have been under considera-

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tion for some time. The specifications as now revised will, in the opinion of Committee D-2, fit present-day needs better than those originally issued. The new specification provides for five grades of oil instead of six as in the old requirements. Certain changes in the methods of testing have been incorporated, including for Grade No. 6 the use of the new test for sediment in fuel oil by extraction (D 473-38 T) which is based upon the methods used by the Federal Specifications Board for many years.

There has also been included in the new standard an adaptation of the distillation procedure for obtaining 10 percent residuum for determination of carbon residue in Grades Nos. 1 and 2 (Grade No. 1 covers a distillation oil for use in burners requiring a volatile fuel and Grade No. 2 covers a distillate oil for use in burners requiring a moderately volatile fuel).

A number of modifications have been made in the detailed requirements for oil, including the deletion of the previous Grade No. 4. The maximum flash point for No. 1 has been raised to 165°F. as previously, and for No. 3 grade the maximum is 230°F. instead of 200°F. The minimum flash point for No. 5 Grade, a medium viscosity fuel is now 130 or legal in place of the prior 150. Grade No. 3, a low viscosity fuel, has a new maximum pour point of 20 instead of 15 as previously.

The maximum carbon residue requirements for Grade No .1 is 0.05 percent on 10 percent residuum but this can be increased to a maximum of 0.12 percent when the oil is to be used in other than sleeve-type blue-flame burners. The limit may be specified by mutual agreement between the purchaser and the seller. For Grade 2, the 0.25 maximum on 10 percent residuum can be reduced to 0.15 percent to meet certain burner requirements.

Copies of the revised fuel oil specifications and the new test for sediment can be obtained in separate pamphlet form from A.S.T.M. headquarters, 260 S. Broad St., Philadelphia, at 25 cents each. Reduced prices apply on orders in quantity.


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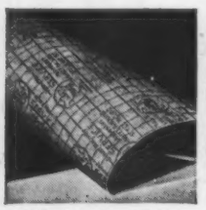

J-M Service Sheet. Pliable. Resilient. Adaptable to all general sheet packing purposes.

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FOR *complete* information on J-M's *complete* line of packings for the oil industry, send for the J-M Packings Catalog. Address Johns-Manville, 22 East 40th St., New York City.

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For Every Oil Industry Service

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## Oil Men Invited to 1938 World Power Conference

AMERICAN oil men have been invited to attend the Vienna Sectional Meeting of the World Power Conference, scheduled for August 25 to September 2, 1938, in the Konzerthaus at Vienna, Austria. Papers and discussions will concern the supply of energy for agriculture, small-scale industries, household purposes, public lighting, and electric railways.

Application forms and information may be obtained, and arrangements made, through the United States National Committee, World Power Conference, 4 Irving Place, New York.

Plans contemplate post-conference journeys to Vorarlberg, Innsbruck, Salzburg, Salzammergut, Badgastein, Worthersee Lake, and other points of interest at reduced rates.

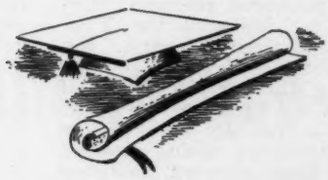
## Bituminous Conference Proceedings Available

THE proceedings of the Montana National Bituminous Conference, held at Glacier National Park, during September of 1937, have been published by the Montana State Highway Department, Helena, Montana, and Western Petroleum Refiners Association, Tulsa, Oklahoma. This 554-page volume presents the papers delivered before the conference on research in bituminous roads and road-building materials, developments in construction, progress in design, and details of maintenance, with discussion and comments on each address. The proceedings will prove of interest to those engaged in production of road-building bitumens and for those interested in the construction and maintenance of low-cost, bituminous highways.

## 104 Items on A.S.T.M. Annual Meeting Program

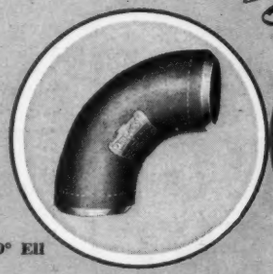
IN the seventeen formal sessions of the Forty-first Annual Meeting of the American Society for Testing Materials held at Chalfonte-Haddon Hall, Atlantic City, June 27 to July 1, inclusive, 104 technical papers and reports covering important topics on a large number of engineering materials were presented. Dr. A. E. White, president, in his annual address discussed "Industrial Research." For many years director of the department of engineering research, University of Michigan, he considered various questions affecting research in

THE *Class* OF '38



# WELDING MIDWEST FITTINGS

45° Ell



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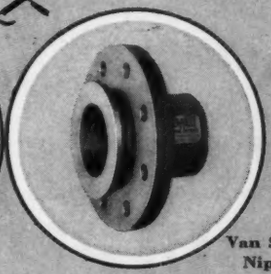
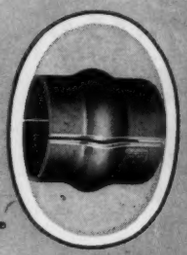


Van Stone Nipple



Sleeve

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If you have a job that requires welding fittings of the highest quality—choose from the "Class" of '38.

Write for Bulletin WF-36 which will give you all the facts about Midwest Welding Fittings.

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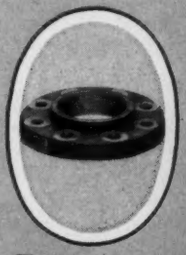
Shaped Nipple

Saddle



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*Main Office:* 1450 S. Second St., St. Louis, Mo.

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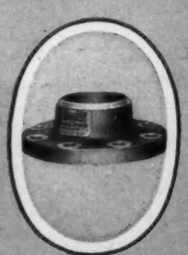
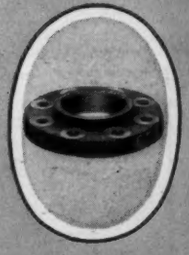
Tee

Return Bend

Reducer



Butt Flange



Slip-on Flange

company laboratories and also in the university and related fields.

Dr. Albert Sauveur, metallurgical engineer and professor emeritus, Harvard University, delivered the Thirteenth Edgar Marburg lecture. His topic "The Torsion Test" is one on which there is a conspicuous lack of information in the technical literature. He described a specially built torsion machine and discussed results obtained at Harvard. Data covered torsional testing of various steels at room and elevated temperatures in the blue-heat range, reverse twisting and the twisting of single crystals. Doctor Sauveur outlined the significance of the autographic torque-twist curve and the desirability of a close study of the torsion test from the standpoint of a routine testing method.

Honored by many governments, universities and societies, Doctor Sauveur, especially renowned for his work in metallography and heat-treatment of iron and steel, has been a member of A.S.T.M. from its beginning, was a member of the old International Association for Testing Materials beginning in 1896.

Doctor White's address and the award of honorary memberships were part of the formal opening session on Tuesday morning, June 28. Committee meetings were in progress all day Monday, and throughout the week.

The first of the two sessions devoted to the Symposium on Impact Testing, with a number of interesting technical papers, was Tuesday afternoon, running concurrently with the session on water. The first impact session covered basic theory and present-day uses—the evening session involved impact tests on welded specimens and a summary.

Five technical papers and a report made up the session on radiography Wednesday morning. Two sessions on concrete and cement were provided, one on Wednesday morning, with three formal papers and the report of Committee C-9, which had three papers appended; the other, Wednesday evening, with three reports and four papers.

Two papers appended to the report of Committee E-4 on Metallography covered the plastics mounting of specimens and examining metals in polarized light. A discussion of methods of testing thermometers was a part of the report on methods of testing. These were included in the seventh session on Wednesday afternoon.

In addition to the cement and concrete session Wednesday evening, there was a particularly interesting one on effect of temperature and fatigue of metals. The report of the joint research committee on effect of temperature had four appended papers, and there were five formal papers, plus the report on fatigue of metals.

Steel, ferro-alloys, and corrosion topics comprised the eleventh session Thursday morning which ran simultaneously with one devoted to bituminous materials, road materials and soils (three reports and three papers).

Ceramics and masonry materials were the topics covered in the thirteenth session, on Thursday afternoon. The two Thursday evening sessions involved iron (four reports and three papers) and petroleum products and fuels (five reports with two papers). The meeting closed on Friday morning, July 1, with two concurrent sessions, one on non-ferrous metals, with two technical papers and nine reports and the other devoted to textiles, paint, and plastics (eight reports, three papers).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More than the leading manufacturer of cooling equipment—MARLEY is also the foremost organization of engineers specializing in this particular phase of mechanical science.

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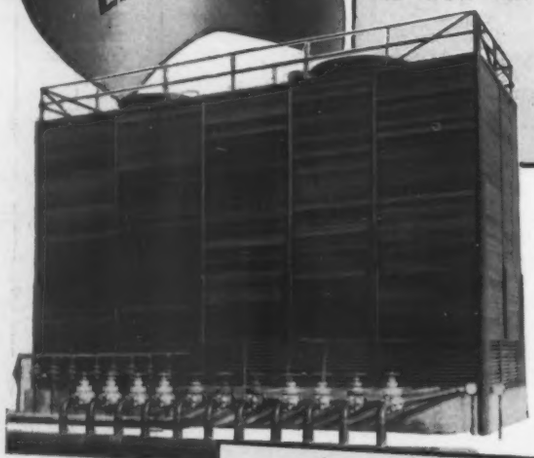

This tower combines closed-system jacket-water and hot gas cooling. Each is circulated through special heat-exchange coils at the base. Two big MARLEY fans at the top actuate the induced draft.

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The MARLEY Company

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## Oil Is $200,000,000 Crop For American Agriculture

OIL seldom is regarded as a farm crop, yet it's worth about $200,000,000 a year to American agriculturists!

Farmers are among the first direct beneficiaries of oil development, records of the American Petroleum Institute show. They take their profit from the time exploration is begun on their lands, and regardless whether oil eventually is located, receive their rental fees.

Rentals and royalties received by farmers add about $200,000,000 annually to farm income in oil sections. In many states these payments vastly exceed federal government aid. For instance, in California, which is a great agricultural as well as oil-producing state, oil rentals and royalties in 1937 totalled $28,203,000 as compared with government payments of $6,082,000. In Texas, whose land area constitutes about one-twelfth of the entire United States, 1937 oil rental and royalty payments reached $105,000,000 as against government payments of $38,226,000.

# BADGER EXPANSION JOINTS

# The Maintenance-Free Way to Handle Pipe Expansion

Many pipe lines in and about refineries are subject to temperature differentials. So what about expansion and contraction?

Both the Stainless Steel and Copper BADGER Directed Flexing, Self Equalizing Expansion Joints offer several economies in handling such problems.

**1... being "packless," no packing or other maintenance is required after the joint is installed.**

**2... being very compact, it saves in room yet takes care of considerable expansion (up to 6 inches single and 12 inches double).**

**3... being the well-known Directed Flexing Joint, the life is materially greater than with the older style joint with straight-sided corrugations.**

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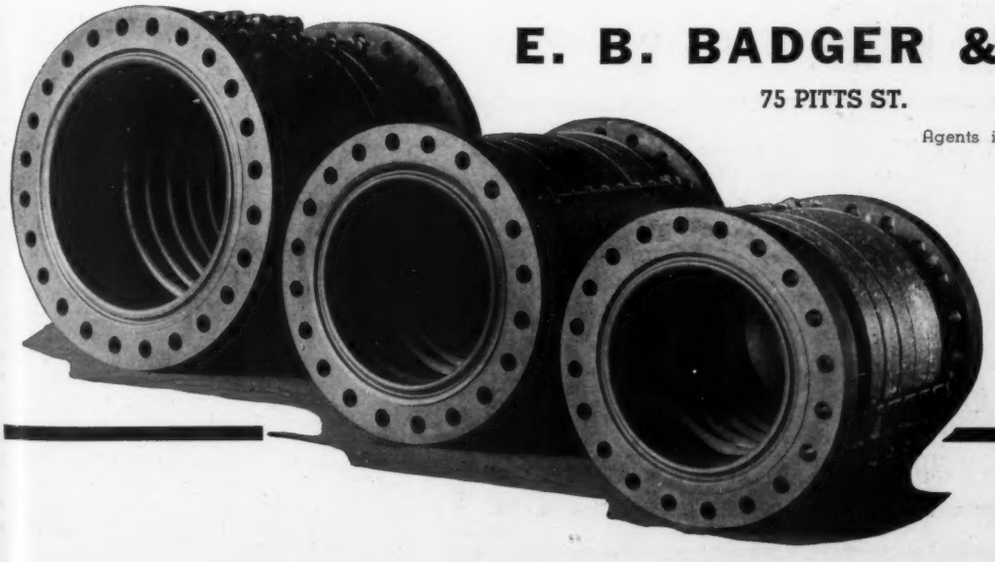
As stated above, BADGER Directed Flexing Joints are made in both Stainless Steel and Special Deoxidized Copper. Thus, the refinery can use the "packless" joint for practically any expansion problem, even if it involves high pressure, high temperature or corrosion.



## E. B. BADGER & SONS CO.

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Agents in Principal Cities

## Carbon-Black Sales Up; but Prices Lower in 1937

ADVANCES in production and total sales, and a slump in prices the latter part of the year were important developments recorded by the carbon-black industry in 1937, states the Bureau of Mines, U. S. Department of the Interior. Production was 510,606,000 pounds, a gain of 24 percent over the previous peak of 1936. A decline in sales the latter part of the year, due to a slowing up in the rubber trade, resulted in an increase of stocks held by producers. There were 100,497,000 pounds of carbon black on hand at the end of 1937 compared with 79,582,000 pounds at the close of 1936.

Spot prices, which had remained remarkably steady since the code, weakened abruptly the latter part of the year. For example, the most representative spot price was 4.45 cents per pound throughout the year until November 8 when a cut of 0.50 cents was made. Several other cuts followed so that this price at the close of the year was only 3.20 cents per pound. The average value at the plants as reported by the producers dropped from 3.92 cents in 1936 to 3.41 cents in 1937, but the average export value advanced from 4.69 cents in 1936 to 4.72 cents in 1937.

Gains in production were registered by all the producing states. The Texas Panhandle again accounted for nearly 80 percent of the total production. Kansas entered the field for the first time with a plant in Grant County. There were 57 carbon-black plants operated in 1937, compared with 54 in 1936. A loss of three plants in Louisiana was more than offset by a gain of 5 plants in Texas and one in Kansas. Ward and Winkler counties, Texas, showed production for the first time, while Moore County (Panhandle) materially increased its output with four new plants.

There were 341,085,000,000 cubic feet of natural gas burned at carbon-black plants in 1937 compared with 283,421,000,000 cubic feet in 1936, or about 14 percent of the estimated gas consumption in the United States in 1937 compared with 13 percent in 1936.

The average yield of carbon black per thousand cubic feet of natural gas rose from 1.45 pounds in 1936 to 1.50 pounds in 1937, the largest gain ever recorded for any single year. This increase reflects a gain in the relative importance of "other" processes, one or two of which recover up to 10 pounds per thousand cubic feet burned.

Sales of carbon-black by the producers rose from 467,736,000 pounds in 1936 to 489,615,000 pounds in 1937. Exports increased from 154,718,000 pounds in 1936, to 184,030,000 pounds in 1937, hence domestic sales decreased from 313,018,000 pounds in 1936 to 305,585,000 pounds in 1937. Domestic sales were divided as follows: To rubber companies, 269,807,000 pounds (88 percent); to ink companies, 18,116,000 pounds (6 percent); to paint companies, 6,159,000 pounds (2 percent); for miscellaneous purposes, 11,503,000 pounds (4 percent). These data indicate losses in the rubber and paint trades, gains for ink and miscellaneous uses.

The United Kingdom continued to be the principal foreign customer followed by France, Germany, and Canada in the order named. Although the continued rise in export was one of the few bright spots in the industry in 1937, a material part of this trade was based on military activities of uncertain duration.

## Plans for 1939 Oil Show at Houston in Progress

AFTER making a careful survey as to the desires of those exhibiting at the Houston Oil Show, the Executive Committee recommended that the next Oil-World Exposition be held in Houston from April 24 to 29, inclusive, 1939. At a meeting of the Board of Directors this recommendation was approved unanimously and all arrangements made to carry out the plans for the 1939 show.

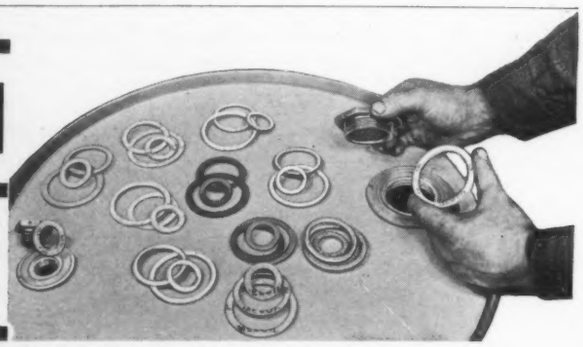
In order to determine the desires of the manufacturers and suppliers of oil equipment, the question was submitted: Do you favor holding the Oil-World Exposition in Houston every two years, alternating with the Tulsa Exposition? Of a total of 221 replies received, 192 companies preferred an exposition held every two years in Houston and every two years in Tulsa. There were 13 companies that wanted the expositions held every four years in Houston and every four years in Tulsa. One manufacturer was satisfied with either arrangement and the rest of those replying to the questionnaire sent out expressed various desires such as a show every 18 months at each city. In all cases there was a desire for an exposition at both Houston and Tulsa.

More than 400 exhibiting spaces in the main building have been reserved for the 1939 Exposition in Houston, announced Ed G. Lenzner, general manager. A great number of exhibitors in the 1937 show have increased their space. In order to accommodate the demand for greater exhibiting space, a large annex has been constructed adjacent to the Coliseum where the last show was held. This annex will provide an additional 90,000 square feet of floor space of which 46,000 square feet are on the same level as the main floor of the Coliseum and 44,000 square feet on the ground floor. In addition 13,300 square feet of exhibiting space has been made available in the basement of the Coliseum which will give a total of 184,742 square feet or 938 exhibit booths.

Approximately 50 percent additional outdoor space has been provided adjacent to the Coliseum to accommodate the largest exhibits such as derricks, drilling rigs, engines, etc. In addition to the previous outside exhibitors, practically all of whom have reserved space for the 1939 show, a number of other companies not previously exhibiting have made inquiries regarding large blocks of outdoor space.

Many important meetings and conventions are also being planned to be held during the Exposition. Fifteen meeting rooms have been completed in the Coliseum and a large convention hall is immediately adjacent to this building. The convention hall is air conditioned and is equipped for sound and has projection booths, a 90-foot stage and offers all the facilities desired for any type of meeting. The seating capacity is 2416.


DRUM PLUG GASKETS • • •



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FOR economy and efficiency in your truck deliveries, install this newest and smallest of Smith Meters—Model 3T-40! With the precision of a fine watch, this positive displacement meter measures accurately, practically to the drop! Its unmatched accuracy is made possible by the Smith *exclusive* meter principle which measures liquid "on the flow" with less friction and consequent greater speed.

Smith rotary-type action permits unimpeded flow and exact cubic measurement whether rate of flow is maximum, slow, or fluctuating.

Model 3T-40 has a normal capacity of 40 g.p.m. With a maximum of 50 and a minimum of 4 g.p.m., it is an ideal meter for tank truck, fuel truck, small bulk plants, marine terminals, barrel fillings, and other applications where compactness and light weight are important considerations.

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Attesting to its accuracy and dependability, the new 3T-40, like other Smith Meters, already has earned the approval of the Massachusetts Department of Weights and Measures, as well as the approval of major and independent oil companies.

The introduction of 3T-40 again broadens the wide range of sizes and types of Smith Meters available for nearly all truck, bulk plant, and refinery applications. For complete information, write Smith Meter Co., Roosevelt Building, Los Angeles, California or any office listed below. Complete stocks carried at all branches.

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**Combinations Available:** *Model 3T-40 is available with horizontal reset counter, or 10-inch, or 6-inch vertical counters. Meter can also be equipped with a ticket-printing register and automatic set-stop.*

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# ▼ PLANT ACTIVITIES ▼

**Gas Purification:** Producers Gas Company, Hays, Kansas, is erecting a Girbotol gas purification plant for removal of hydrogen sulfide. This is the third Girbotol to be built in the Otis field near Hays and when it is completed all gas taken from the field by five pipe line companies operating there will be purified by this process.

**Gasoline Plant:** Hammond Exploration Company is building a new high pressure absorption type natural gasoline plant in the Bay City, Texas, area, with contract to Western Supply Company, Tulsa. Plant cost is reported at $100,000.

**Recondition:** Texas Oil Products Company, Gladewater, E. L. Ames, president, is reconditioning its 5000-barrel refinery with cracking facilities and will place the plant in operation.

**Refinery:** Alice Sidney Oil Company is planning erection of a new refinery near El Dorado, Arkansas, to operate on crude from the Schuler field.

**Polymerization:** Standard Oil Company of Louisiana is building a new catalytic polymerization unit and is erecting an addition to its large hydrogenation plant at Baton Rouge. The company recently completed erection of a propane dewaxing plant to process phenol-treated residuum and other lubricating oil stocks.

**Repairs:** Chalmette Petroleum Corporation, New Orleans, following a furnace fire, has completed reconstruction of the furnace and installation of new tubes and other damaged equipment.

**Refinery:** Southport Petroleum Corporation with refineries at Texas City and Kilgore, Texas, is mentioned in trade reports as planning construction of a new skimming and cracking type of refinery in the New Orleans, Louisiana, area.

**Modernization:** Arkansas Fuel Oil Company (Cities Service) is reported planning an extensive modernization program to include installation of combination cracking and polymerization facilities at Shreveport, Louisiana.

**Gasoline Plant:** Inglewood Gasoline Company, Wilmington, California, has purchased a gasoline plant from State Gasoline Company and is moving it to a new site in the Wilmington field.

**Refinery:** British American Oil Company, Ltd., Calgary, Alberta, Canada, is negotiating for site and certain tax concessions which if successful will mean the establishment of a 4000- to 5000-barrel refinery in Calgary, at a reported cost of around $1,350,000.

**Refinery:** Producers Refining Company, Shelby, Montana, has announced plans for construction of a new 3000-barrel refinery in northern Montana, with definite location not yet decided upon.

**Operating:** Premier Oil Refining Company, Longview, Texas, has resumed operations after several months shut down and is running 2500 to 3000 barrels a day.

**Refinery:** Producers Refining Company, Shelby, Montana, is reported planning construction of a 2000-barrel modern refinery to cost approximately $650,000.

**Remodel:** Shell Petroleum Corporation is enlarging and remodeling its compression type natural gasoline plant in the Healton field, southern California, converting it to absorption system at increasing capacity from 2500 to 8000 gallons a day. Cost reported at $150,000.

**Refinery:** Greens Bayou Refining Corporation, Houston, J. A. Parker, president, is erecting a small skimming type refinery on Green's Bayou about one quarter mile off the Houston Ship Channel. Reported capacity is 1000 barrels. Company has leased a five-acre tract for five years with option for ten years additional. Oil from Jennings,


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...and a famous Process that keeps pace with its development

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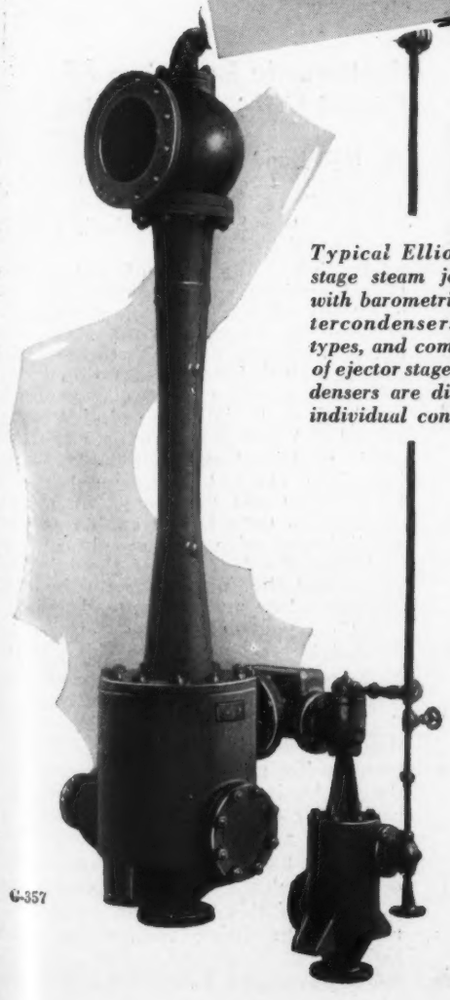
# Startling figures on VACUUM savings—

**Older type steam jet ejector**

**Modern ELLIOTT steam jet ejector**

| | |
|---|---|
| Steam Consumption, Old Unit—4070 lb. per hr. | |
| Steam Consumption, New Unit—1600 lb. per hr. | |
| **STEAM SAVING 2470 lb. per hr.** | |
| Increment Cost (Fuel Only) Steam—$0.17 per 1000 lb. | |
| Steam Saving—2.470 x 0.17= | $0.4199 |
| Water Consumption, Old Unit—625 g.p.m. | |
| Water Consumption, New Unit—330 g.p.m. | |
| **WATER SAVING 295 g.p.m.** | |
| Water Saving—295 x 60=17,700 g.p.hr. | |
| Water Pumping Cost—$0.005 per 1000 gal. | |
| Water Saving—17.7 x $0.005= | $0.0885 |
| | $0.5084 |
| Total Saving per hour | |
| Hours Operated per year—7446 | |
| **SAVING PER YEAR—7446 x $0.5084=** | **$3785.75** |
| Cost of New Unit, including freight and installation | $2900.00 |



G-357

*Typical Elliott three-stage steam jet ejector with barometric type intercondensers. Sizes, types, and combinations of ejector stages and condensers are dictated by individual conditions.*

**"When the man bites the dog, it's news" — similarly, while there is nothing remarkable in a steam jet ejector installation saving plenty over other methods of maintaining vacuum, it certainly is news when a *modern* ejector in one year saves its own cost, plus upward of $1,000, *over another ejector installation.***

**The answer is, that while all ejector vacuum applications are good, some are better than others — and a good deal better, as a glance at the cost analysis above will show. The particular refinery in which this occurred, now has replaced a second old type ejector with a modern Elliott 3-stage ejector, and two similar replacements were made in another refinery of the same company. Some of these units have now been working for two years, with no let-up in savings, and with no appreciable wear of nozzle or diffuser bores.**

*Look over your vacuum apparatus now. Perhaps Elliott ejectors can save you money. Bulletin G-6 will help — so will our experienced engineering department.*

## ELLIOTT COMPANY

*Heat Transfer Department*
JEANNETTE, PA.
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Louisiana, is to be processed and will be brought to Houston in barges.

**Cracking:** Eastern States Petroleum Company, Houston, Texas, has acquired a more liberal type of license from Gasoline Products Company, and has revamped its modern 10,000-barrel refinery to take advantage of the rights obtained under the new license arrangement. The company has been actively pursuing a program of refinery improvements with the assistance of Gasoline Products Company since acquiring a limited license from it early in 1937.

**Purchase:** Mutual Oils, Ltd., Edmonton, Alberta, Canada, has purchased a refinery in Mt. Pleasant, Michigan, and is moving the equipment to the new Canadian site. The plant was never operated. Purchase price is reported at $150,000; capacity 1000 barrels.

**Chemicals Plant:** The Carbide & Carbon Chemicals Corporation, subsidiary of Union Carbide & Carbon Corporation, is to build a large chemical plant at Texas City on a site recently purchased near the refinery of Pan American Refining Corporation. The initial expenditures are to total $2,500,000, while the complete project will involve expenditure of around $4,000,000.

**Cracking:** Magnolia Petroleum Company is nearing completion of construction at Beaumont, Texas, two new cracking units designed under the Houdry patents. The parent company, Socony-Vacuum Oil Company, is reported planning erection of Houdry catalytic cracking units at all its own refineries and those of its subsidiary companies.

**Cracking:** The Pure Oil Company is progressing rapidly with construction of its new 22,000-barrel combination cracking unit at Nederland, Texas, with completion scheduled for September. Contract to Lummus Company.

**Distillation:** The Texas Company is nearing completion of its 16,500-barrel two-stage crude distillation unit at Port Neches, Texas. It is designed for use in asphalt manufacture.

**Modernizing:** Gulf Oil Corporation continues to modernize its large refinery at Port Arthur, Texas, and the work includes a polymer hydrogenation plant designed under the Hydro patents, a new U.O.P. catalytic polymerization plant, a combination selective cracking plant of 22,000 barrels capacity, and a 5000-barrel vacuum redistillation unit, with general repair and modernization work affecting many other departments.

**Polymerization:** Shell Petroleum Corporation is building a gasoline absorption recovery plant, a stabilization system and a new polymerization plant at Norco, north of New Orleans, Louisiana. Cost of the new work totals around $700,000.


# Why 15 REFINERIES Recently Ordered 26 Troy-Engberg Steam Engines

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DEPENDABLE

High-starting and high-running torque

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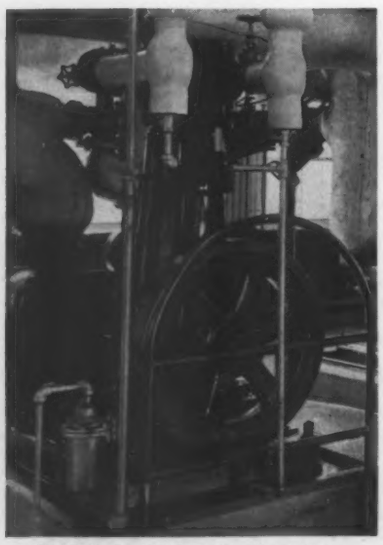
**to obtain DEPENDABILITY ECONOMY AND CERTAIN OPERATING FEATURES**



One of several Troy-Engberg Steam Engines driving pumps in the Port Arthur Refinery of The Texas Co.

**Of the 26 drives referred to above, 17 were for pumps thus still further emphasizing the high rating given the modern steam engine on the question of dependability.**

That the Troy-Engberg Engine is economical is amply demonstrated by the fact that many companies are getting their power at the drive shaft for ½ cent per kwh or less. And the maintenance of these engines is negligible.

As for their desirable operating features, consider those listed above. They apply equally well to horizontal and vertical engines. They are characteristics particularly useful in refineries.

The following bulletins tell the story of the modern Troy-Engberg Steam Engine. Send for copies.

**SURVEY BULLETIN No. 101 telling how 43 leading companies found their average cost with the Troy-Engberg Engine to be only ½ cent per kwh. All costs were included in the survey.**

**Steam Engine Catalogue No. 305**

**Engine Control Bulletin**

**If you are interested in Generating Sets, send for Catalogue 107.**

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## Systematic Location of Diesel Engine Troubles

A NEW and handy wall chart "Systematic Location of Diesel Engine Troubles" arranged by Victor W. Pagé, M.S.A.E. has been published, and is ready for distribution.

The increasing use of automotive Diesel engines and the numerous applications of small and medium powered engines operating on the compression ignition principle, to industrial uses as well as for transportation makes this new chart a particularly timely publication. It is intended for shop, school and garage use and is a valuable guide to Diesel engine trouble shooting. The chart has sectional views, longitudinal and transverse, of a typical modern light Diesel engine as well as diagrams of a fuel supply system, including the feed pump, the injection pump and the fuel injector. The type is large, clear and easily read.

All mechanical parts are clearly indicated by arrows and named and the accompanying tabular matter summarizes the various defects apt to occur, the symptoms that indicate the defective condition and the remedy for the trouble. To make the search easy for the mechanic, the troubles are summarized under easily recognized faulty action such as lost power, hard starting, misfiring, noisy operation, reasons for different color of exhaust smoke, etc.

Copies of this chart can be secured through the Book Department, Gulf Publishing Company, 3301 Buffalo Drive, Houston, Texas. Price 50 cents.

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**PNEUMATIC REMOTE MEASUREMENT AND CONTROL**

# SCIENCE AND TECHNOLOGY

*Abstracts prepared in co-operation with the*

**REFINER AND NATURAL GASOLINE MANUFACTURER**

*by*

**THE LESLIE LABORATORIES**
**Traver Road, Ann Arbor, Mich.**
*under the supervision of*
**DR. E. H. LESLIE and DR. H. B. COATS**

*The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.*

*Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.*

## Fundamental Physical and Chemical Data

**Gas-Liquid Equilibria for the System Methane-Butane,** G. W. NEDERBRAGT *Ind. & Eng. Chem.* **30** (1938) pp. 587-8.

In several processes of the natural gas and gasoline industry pressures higher than atmospheric are used, and as a consequence, information on gas-liquid equilibria of mixtures of lower hydrocarbons under pressure is of great interest. The solubility of methane in hydrocarbons such as pentane and hexane has been determined by various investigators, but they did not examine the composition of the gas phase at the same time. It was therefore considered important to study the composition of both gas and liquid phases in the case of mixtures of methane with a hydrocarbon such as butane. Determinations were made at three temperatures—approximately —20°, 15°, and 40°C.—and at three pressures—10, 20, and 30 atmospheres. Data are presented in tabular form, as is also a graph showing the equilibrium constant calculated.

**Vapor Pressures of Solvents.** D. H. KILLEFFER, *Ind. & Eng. Chem.* **30** (1938) pp. 565-7.

Two additional nomographs are presented covering groups of compounds boiling from 150° to 200°C. and above 200°C. The graphs have been prepared from carefully checked data, and are believed to be accurate within the limits of error of the original data. Those interested in securing these two nomographs, as well as the two published in the April issue of Industrial and Engineering Chemistry, can obtain them by sending 25c to Industrial and Engineering Chemistry, 706 Mills Building, Washington, D. C.

**Specific Enthalpy of Low-Pressure Steam.** C. H. BERRY, *Combustion* **8** (1937) pp. 41-2.

Equations and charts for computing the enthalpy of low pressure steam with an accuracy of 2 percent for the temperature ranges —40° to 316°, 316-592°, and 592-872° are given.

**The Energy of Isomerization of Normal Pentane into Tetramethylmethane.** F. D. ROSSINI AND J. W. KNOWLTON, *J Chem. Phys.* **6** (1938) p. 168.

The determined value of the heat of combustion of $CMe_4$ at 25°C. and 1 atmosphere is $CMe_4$ (gas) + $8O_2$ (gas) = $5CO_2$ (gas) + $6H_2O$ (liquid); $\Delta H = -3516.41 \pm 0.94$ NBS international kilojoules per mole. The energy of isomerization of n-$C_5H_{12}$ (gas) to $CMe_4$(gas) at 25°: $\Delta H + \Delta E = -19.59 \pm 1.24$ kilojoules, or $-4.68 \pm 0.30$ kilogram-calories per mole.

**Accurate Determination of Dew Point.** A. W. HIXSON AND G. E. WHITE, *Ind. & Eng. Chem., Anal Ed.* **10** (1938) pp. 235-40.

Direct dew-point determination affords a sensitive means of determining vapor concentrations. The formation of dew has been utilized as a criterion in the investigation of phase equilibria with reference to motor fuels and hydrocarbon systems under pressure. It was the purpose of the study to improve the accuracy of dew-point indications. The technic is such as to eliminate the marked hysteresis error characteristic of methods involving continuous temperature change. An accuracy of $\pm 0.01$°C. is reached. A double gaseous film adjacent to the liquid phase is hypothesized in explanation of observed phenomena.

## Chemical Compositions and Reactions

**Catalysts in Hydrocarbon Chemistry.** E. K. RIDEAL, *Jour. Inst. Pet. Tech.* **24** (1938) pp. 221-4.

Increasing attention is being paid in hydrocarbon chemistry to catalytic processes. It is shown that these can be formulated on the basis of a radical mechanism. Homogeneous reactions can be brought about by free radicals and heterogeneous reactions by chemi-adsorbed radicals. The energy of activation of such heterogeneous processes is less than one fourth of the corresponding homogeneous reactions. This permits of lower temperature operation, greater efficiency and better control. The use of o.p. hydrogen and of deuterium as tools for the elucidation of the mechanism of hydrogenation is briefly indicated.

**Mechanism of Polymerization of Pure Olefines.** F. JOSTES AND W. BARTELS, *Oel u. Kohle* **13** (1937) p. 1166.

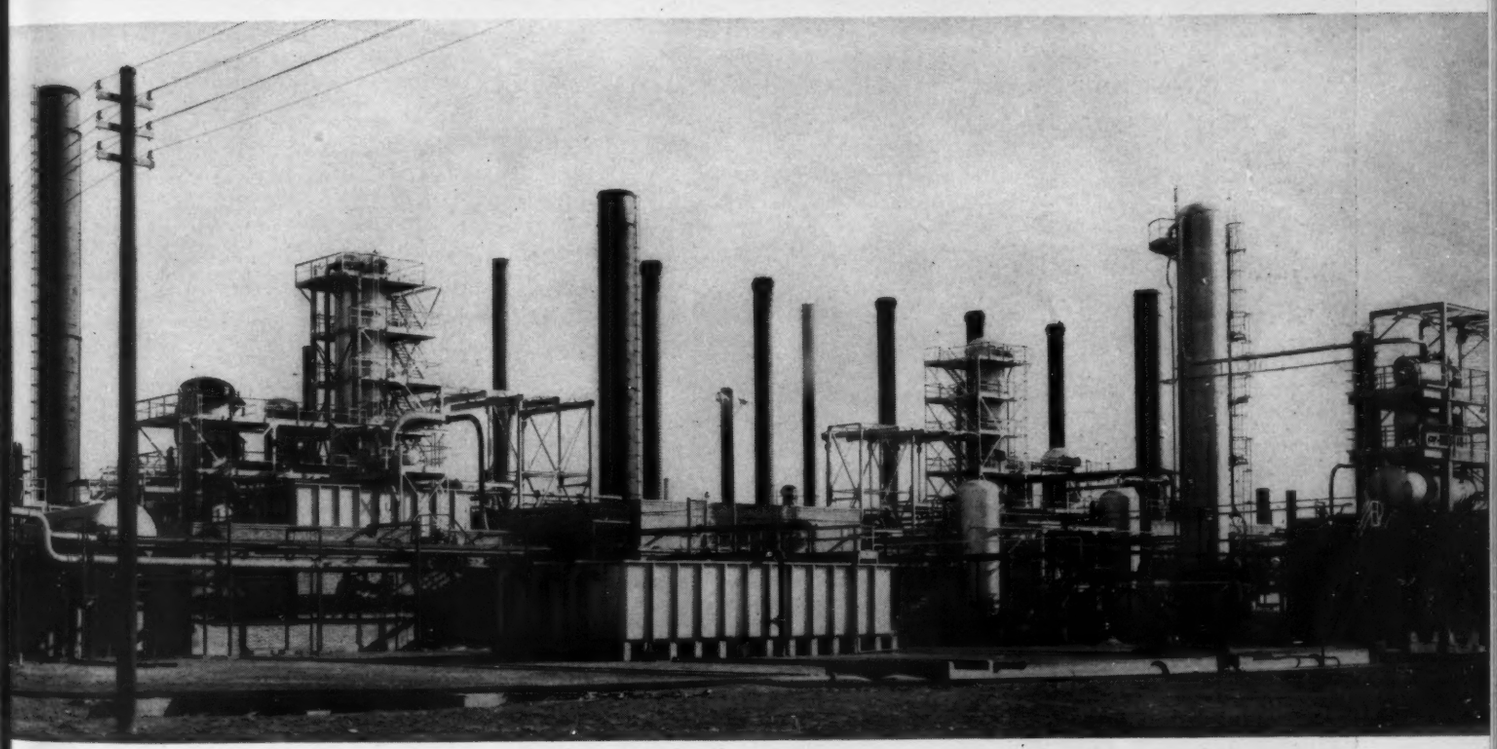
An effort was made to establish the course of polymerization by examination of intermediate polymers. The mild catalyst $P_2O_5$ was used. Heptene gave a low-boiling, unsaturated inttrmediate product, the properties of which suggested a dimeric structure, the molecules joining together to give a branched-chain, and not a straight-chain polymer. Small proportions of tri- and tetra-mers were obtained. Attempts to establish the position of unsaturated linkages in the polymers by means of ozonolysis failed because ozone was found to react with both the saturated and unsaturated carbon linkages. Higher olefins such as octene and dodecene gave no more than dimers even under relatively severe conditions. In the case of propene, no intermediate products were identifiable, but it is believed that the polymers were chiefly branched-chain hydrocarbons.

**Mixed Polymerization of Butenes by Solid Phosphoric Acid Catalyst.** V. N. IPATIEFF AND R. E. SCHAAD, *Ind. & Eng. Chem.* **30** (1938) pp. 596-9.

The fact that heptenes are formed by the mixed polymerization of butenes and propene suggested the possibility of producing octenes of highly branched structure by mixed polymerization of isobutene with normal butenes. According to expectations, it was found that the formation of such isooctenes followed by hydrogenation yielded octanes of high anti-knock value suitable for use in the production of aviation gasoline. Working under 7.8 atmospheres pressure at 95-120, 177, and 120°C. produced polymers containing, respectively, 70, 55, and 74-80 percent of octenes that hydrogenated to octanes of 98-100, 83-85, and 95-97 octane numbers. Polymers formed from mixtures of isobutene and n-butene under 42 atmospheres pressure at 149°C. contained 88 percent by volume of octenes that hydrogenated to octane of 95 octane number. For the production of octanes of high anti-knock value, polymerizing iso- and n-butene mixtures was found superior to mixing the polymers formed separately from each of these butenes. For example, octane derived from 50 percent isobutene and 50 percent n-butenes by mixed polymerization and hydrogenation had an average octane number 3.5 points higher than that of an octane blend composed of 50 percent hydrogenated di-n-butene and 50 percent hydrogenated diisobutene. The data are presented in some detail in tabular form, and a bibliography of 18 references is given.

**The Reaction of Cycloparaffins with Aromatic Hydrocarbons: Decycloaklylation.** A. VON GROSSE AND V. N. IPATIEFF, *J. Organic Chem.* **2** (1937) p. 447.

The authors studied the catalytic treatment of aromatic hydrocarbons with cycloparaffins. They term the process "decycloalkylation" since the reaction proceeds through a splitting of the cycloparaffin ring followed by alkylation of the aromatic hydrocarbon by the severed-ring paraffin. Benzene was easily alkylated with cyclopropane at 25-30°C. by passing the pure dry gas for 30 hours into a mixture of benzene and powdered C.P. aluminum chloride activated with a small quantity of hydrogen chloride. The cyclopropane reacted completely and no gas was evolved. The upper layer contained 38 percent of unchanged benzene, 29 percent of n-propylbenzene, 12.8 percent of dipropylbenzene, 12.7 percent of tri- and higher propylbenzenes, and 6 percent of hexapropylbenzene. Of special interest was the isolation of the hitherto unknown hexa-n-propylbenzene. This substance crystallized from hot alcohol in large flat white plates, melting point 103°C., boiling point 332°C., and density at the melting point 0.8163. It was found that methylcyclobutane and benzene react readily at 20°C. in the presence of aluminum chloride three times, giving principally a mixture of isoamylbenzene with at least one other isomeric



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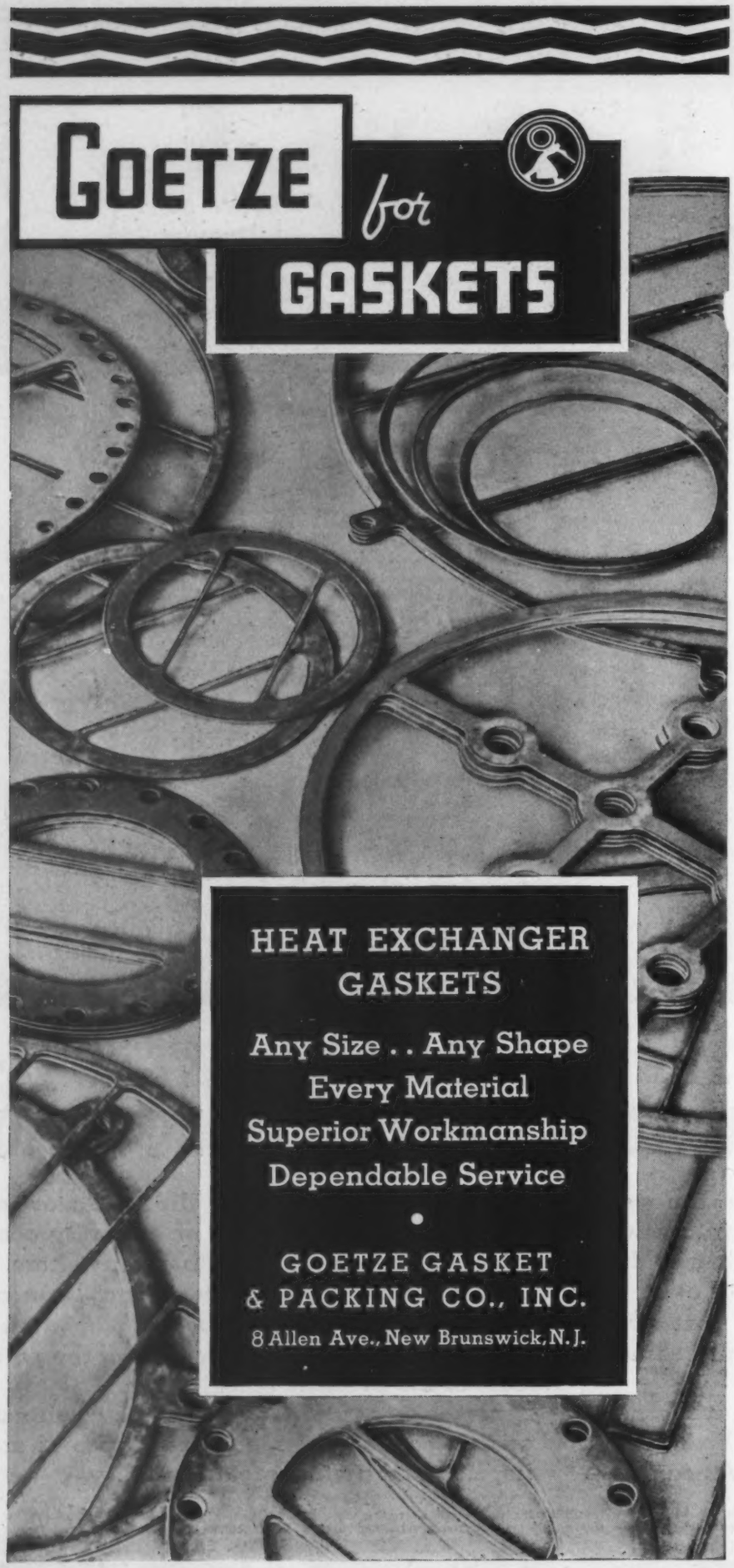


amylbenzene, probably 2-phenylpentane, and various quantities of higher amylbenzenes. The reaction of cyclopentane and benzene was slower; it required a temperature of 150°C., and although the expected amylbenzene and its homologues were identified, they were contaminated with quantities of ethylbenzene, toluene, etc.

**The Hydrogenation of Ethylene by Iron Synthetic Ammonia Catalysts.** R. C. HANSFORD AND P. H. EMMETT. *Jour. Am. Chem. Soc.* **60** (1938) pp. 1185-90.

The investigation was undertaken in order to ascertain the activity toward ethylene hydrogenation of typical iron synthetic ammonia catalysts. The hydrogenation reaction was studied in the range of temperature between —40 and —89°C. The reaction on the promoted iron catalyst in this temperature region was considerably slower than on unpromoted iron. The promoter of the synthetic ammonia catalyst appears to inhibit the hydrogenation of ethylene. Evidence is presented that indicates that the activated adsorption of hydrogen alone is involved in the reaction, ethylene being physically adsorbed. The lower temperature type of activated hydrogen adsorption plays the dominant part in the reaction.

**Thermal Decomposition of Hexane at High Pressures.** J. N. PEARCE AND J. W. NEWSOME, *Ind. & Eng. Chem.* **30** (1938) pp. 588-92.

Although considerable work has been done on the thermal decomposition of paraffins at low pressures, relatively little work has been done at high pressures. The present paper presents the results obtained in a study of decomposition of n-hexane under very high pressures. Hexane was selected since its decomposition at low pressures was recently rather fully investigated by Frey and Hepp. The thermal decomposition of hexane was studied by the authors at pressures of 14,000 to 15,000 pounds per square inch, and at 10°C. intervals between 430° and 520°C., and for periods of time varying from a few minutes to 2 hours. Decomposition occurs in every instance to form compounds boiling both higher and lower than hexane. Carbon was deposited in some cases. The gaseous products boiling below 100°C. are chiefly aliphatic in nature. In the products boiling above 100°C. the cycloparaffins predominate with appreciable amounts of aromatics and some olefins. The data are presented in some detail in tabular and graphical form, and a bibliography of 12 references is appended.

**Thermal Decomposition of n-Octane.** R. F. MARSCHNER, *Ind. & Eng. Chem.* **30** (1938) pp. 554-62.

Because of the lack of complete and accurate thermal decomposition data upon normal paraffins between hexane and hexadecane, the behavior of n-octane in the neighborhood of 570°C. and at atmospheric pressure was studied. The n-octane employed was obtained without difficulty, and in satisfactory yield and purity, from Mid-Continent petroleum. The effect of temperature, extent of decomposition, and nature of the apparatus in which the pyrolysis was effected were studied. Thermal decomposition at atmospheric pressure and 571°C. led to a long but simple series of products that differed quantitatively from those predicted by the free-radical theory in the amounts of ethylene and of the heavier olefins formed. The product analyses were the same when decomposition was increased from 18 to 33 percent, and carried out in Pyrex glass instead of stainless steel apparatus, and differed but little from those obtained at 538°C. A slight revision of the free-radical theory improves somewhat its agreement with the experimental data. The effect of a carbonized surface upon the pyrolysis was studied, and the bearing of these results upon the theory of thermal decomposition is discussed. The liquid products obtained were thoroughly examined for evidences of rearrangement of olefins and of isomerization of the carbon skeleton. The ethylene deficiency cannot be readily explained, but the amounts of higher olefins can be accounted for by assuming that the octyl radicals break unequally in the two possible directions. At temperatures below 571°C. stainless steel apparatus which has been in continuous use for an extended period gave products that contained abnormally large amounts of methane. The other products were not greatly changed. Above 571°C. methane and hydrogen resulted to the exclusion of heavier products. Fractionation and chemical treatment of the liquid decomposition products showed that the saturated hydrocarbons retained the linear structure of the n-octane, as assumed by the free radical theory, but that the 1-alkenes apparently first produced were accompanied by small amounts of other unbranched alkenes and cycloalkenes. A bibliography of 54 references is appended.

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**The Science of Petroleum.** Editors: A. E. DUNSTAN, A. W. NASH, B. T. BROOKS, AND SIR HENRY TIZARD, Four Volumes, pp. 1-3192. (London: New York and Toronto: Oxford University Press) 15 pounds, 15s. net.

For about 15 years no work or reference has been published dealing with the entire field of the petroleum industry. A revision of any previous work was thought to be impracticable by the editors, because the changes in technology have been so extensive as to require an entirely new approach. The developments in technology have long outstripped the ability of any single author to deal with them authoritatively. In the preface to the work the editors state: "The records of advances in the science and technology of petroleum are scattered in innumerable journals and in the archives of industrial companies. The purpose of the present work is to provide a balanced and comprehensive treatise that shall be critical in treatment . . . " The individual chapters of the work are really separate scientific papers varying in length from 1000 to 40,000 words, each planned and arranged in its relationship to the whole. The contents are broadly divided into: Volume I, Geology, Production and Transport; Volume II, Chemistry and Physics; Volume III, Refining; Volume IV, Products and Utilization. The entire work comprises approximately three million words in 3192 pages. To review these volumes in any adequate manner is quite impossible in a brief abstract. The work can only be appreciated by actual reference to and study of the contents, which is highly recommended.

**Equilibration of Liquid and Vapor on a Rectifying Pan.** M. RUHEMANN, *Physica* **4** (1937) pp. 1157-68 (in English).

Bozynjakowic's kinetic equations for molecular interchange between a binary liquid and its vapor are applied to determine the time needed for bubbles of vapor to attain equilibrium with a liquid through which they are rising. The resultant formulas were used to compute the effectiveness of contacting plates of an air-separating plant. The results so obtained were compared with the actual results secured through use of the column.

**Effect of Tube Arrangement on Convection Heat Transfer and Flow-Resistance in Cross-Flow of Gases Over Tube Banks.** O. L. PIERSON, *Trans. Amer. Soc. Mech. Eng.* **69** (1937) pp. 563-72.

The convective rate of heat transfer between gases and tube banks, as well as the corresponding pressure drop for transverse flow, were measured to determine the effect of varying the spacing of the tubes. Thirty-eight tube arrangements differing in center-to-center spacing in the direction of flow, and also transversely, were tested. The tubes were all of the same size. The spacing, both for tube rows in line and staggered, varied from the closest practicable to 3 tube diameters. Each bank, with two exceptions, comprised 90 tubes arranged in 10 rows transverse to the air stream, each row containing 9 tubes 0.31 inches in diameter, uniformly heated throughout their length. Heat was transferred to a stream of cool air. Heat input to the bank was kept constant at 72,000 B.t.u./hr. The mass velocity of the air was varied. Data showed that the convective rate of heat transfer and flow-resistance of the tube banks varied markedly with change in tube arrangement. No simple statement of this variation was found possible.

**Effect of Equipment Size on Convection Heat Transfer and Flow-Resistance in Cross-Flow of Gases Over Tube Banks.** E. C. HUGE, *Trans. Amer. Soc. Mech. Eng.* **59** (1937) pp. 573-81.

The effect of tube size as a factor in heat transfer and also in pressure drop for gases flowing transversely over tube banks of a given tube arrangement, was studied, using several different sizes of tubes. Nine different tube arrangements, defined by center spacings in the direction of flow, and also transversely, were used with tubes ½-inch and 11/16-inch in diameter. The spacings range from a minimum of 1¼ x 1¼ to a maximum of 2 x 3 diameter. Ten rows of tubes were used in the direction of flow, and each row was ten tubes wide except for one case in which eight tubes wide was used. In addition, three arrangements of tubes of 2-inch diameter were used in banks ten rows deep and 9-15 rows wide. When using the smaller tubes heat was transferred from hot gases outside the tube to cold water inside the

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tube. When using 2-inch tubes heat was transferred from condensing steam inside to air outside.

**Data on Flow Resistance and Heat Transfer in Cross-Flow of Gases Over Tube Banks.** E. D. GRIMISON, *Trans. Amer. Soc. Mech. Eng.* **59** (1937) pp. 583-94.

The data obtained in the experiment of Pierson and Huge are summarized and discussed by the author.

**Sludge and Sludge Formation in Cracked Residues.** J. VOSKUIL AND I. ROBU, *Jour. Inst. Pet. Tech.* **24** (1938) pp. 181-206.

Several cracked residues from different materials, cracked under varying conditions, were microscopically examined. It was found that the microscopic images varied widely. Some were almost homogeneous even with dark ground illumination, like the straight-run residues, and others contained many inhomogeneities (sludge). In most cases it is impossible, owing, for example, to viscosity, to determine directly the quantity of sludge in residues and in mixtures of residues with gas oil. An indirect method was therefore used. This consisted of determining quantities of precipitate in a residue with varying quantities of a precipitant hydrocarbon (e.g. 60/80 gasoline, and mixtures of gasoline and benzene). The percentages of precipitate were plotted as a function of the quantity of precipitant hydrocarbon. The resultant curve was extrapolated on the graph or with the aid of an empirical formula, to a dilution of the hydrocarbon of zero. The quantity of sludge in the residue was thus found. The occurrence of heater sludge in the preheaters of oil burners when using cracked residues as fuel components was studied. It was found that the conversion of sludge into heater sludge depends on the medium of suspension. If the medium contains too few materials that have a stabilizing effect on the sludge, the latter is converted into heater sludge. Oxidation plays an important part in this regard.

## Products: Properties and Utilization

**New Results of Testing Lubricating Power with Thoma's Oil-Testing Machine.** E. H. KADMER, *Oel, Kohle, Erdol u. Teer* **14** (1938) pp. 147-51.

Thoma's oil-testing machine is described. It comprises two crossed rolls of steel driven by a motor at 50 and 300 r.p.m. respectively. When it rests the rolls are in point contact; in motion the contact describes a helical line for one of the rolls executes automatic axial travel. Since they run in contact and at different velocities, the friction is purely sliding. The rolls are placed in an oil-tight housing that can be heated and filled with the oil to be tested. By sliding weights on a lever the pressure of one roll against the other can be increased. The friction losses are transmitted to a torsion friction balance with friction indicator. The lubricating capacity of oils can only be compared with this apparatus if the oils have the same viscosity. By changing temperature different oils can be tested, as they were in these experiments at 80 and 40 centipoises. Differences in lubricating capacity depend upon the chemical structure of the hydrocarbons. Average friction increased proportionately as load was increased from 200 to 2000 grams, as specific gravity increased, with the viscosity pole height or slope, and with the percentage increase of carbon rings in the molecules. All fatty oils, and particularly the fatty acids, showed lower friction than the mineral oils, while the oils from coal tar, and particularly refined rosin oil, had high friction value. For the hydrocarbon oils there is a dependence between specific gravity and refraction that does not exist in the fatty oils and fatty acids. According to the data secured the paraffin-rich mineral oils are better lubricants than aromatic oils, and there is a definite relationship between the coefficient of friction on one hand and specific gravity, refraction, aniline point, and proportion of carbon rings to carbon chains, on the other hand.

**The Structure of Lubricating Greases.** A. S. C. LAWRENCE, *Jour. Inst. Pet. Tech.* **24** (1938) pp. 207-20.

The authors note that the statement to the effect that a grease is a water in oil emulsion stabilized by soap, or, more vaguely, a colloidal solution of soap in oil, is unsupported by evidence, and is in fact entirely untrue. There exists no public knowledge of the value of greases for the particular purposes to which they are applied, nor of their limitations, nor of

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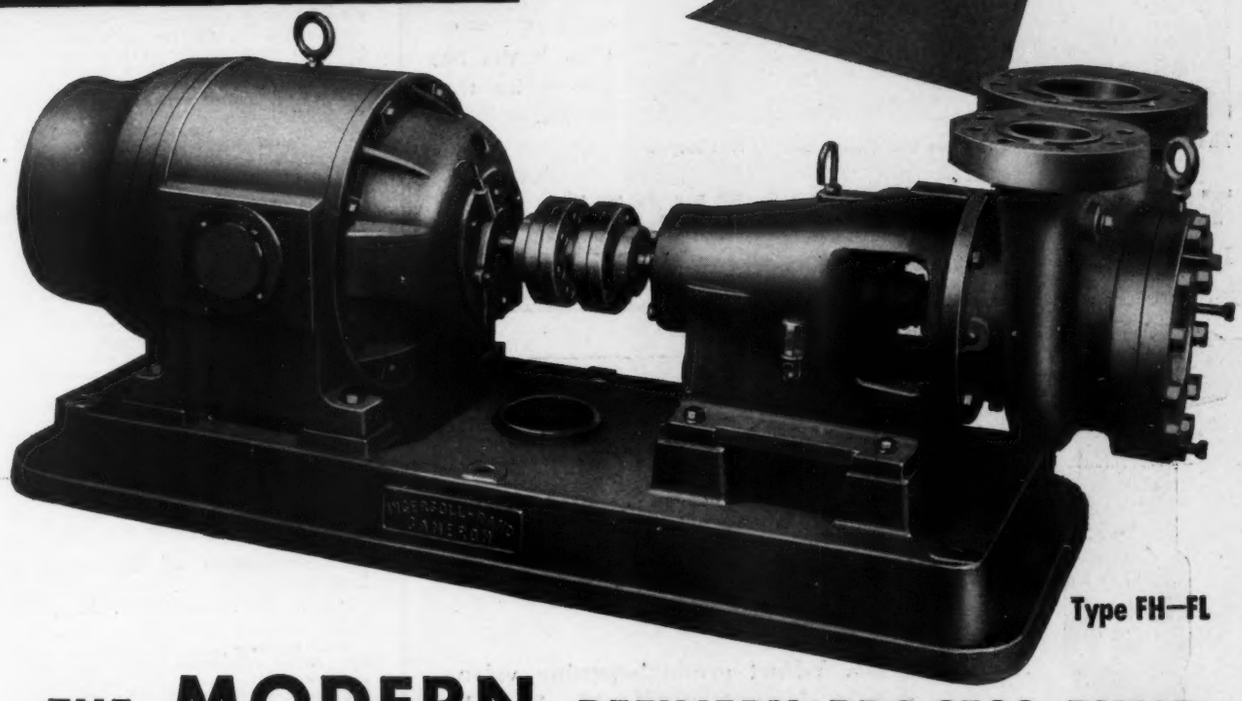

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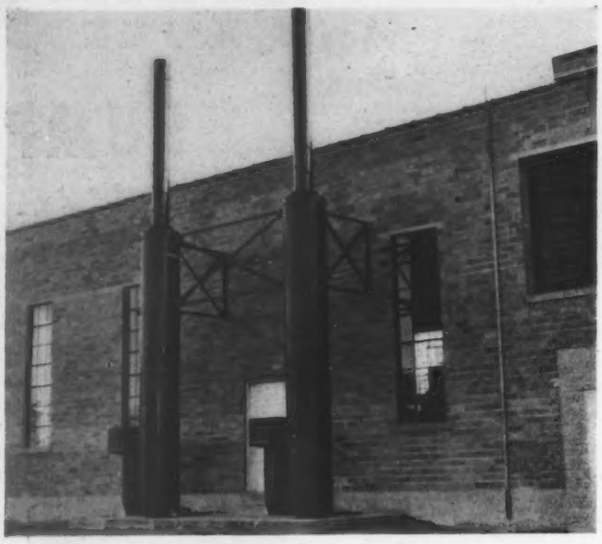

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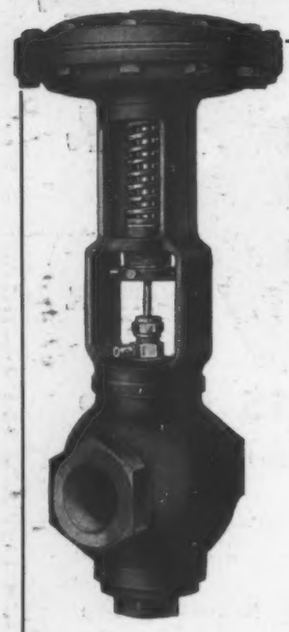

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their optimum composition for various uses. Knowledge of the best methods for the manufacture of greases is the result of experience, and is not based on any fundamental knowledge of the results to be achieved. Work on non-aqueous gels, published in full elsewhere and summarized in this article, throws considerable light upon the nature of greases and on the actual problems that they present. Soap-oil systems exist in three forms: true solution, true gel and pseudo-gel, that is, a paste of micro-crystals. Commercial lubricating greases may be in stage 2 or 3. There is a well-defined temperature of transition from 2 to 3 which depends on the nature of the soap used and upon the presence of polar substances such as fatty acid, water or glycerin, that lower it. These greases are not emulsions. Natural greases such as butter and tallow are emulsions in which the dispersion medium is a soft solid. Dispersion of the soap in the oil can be brought about by stirring at any temperature above that of the transition and does not require raising to that of true solution. Formation of gel and pseudo-gel are crystallizations, and the mechanical properties of the systems are the result of the peculiar crystal habit and properties of the separating soap particles. The properties are profoundly modified by small amounts of fatty acid. Interesting photographs are presented in the article that show the crystalline structure of a typical system of sodium stearate in Nujol.

**Aluminum Stearate Greases.** F. J. LICATA, *Ind. & Eng. Chem.* **30** (1938) pp. 550-3.

Aluminum stearate grease has the advantage of crystal transparency and customer appeal, relatively high temperature resistance, stability, water-proofness, and the possibility of wide application in a variety of lubrication problems. Data are presented to show that grease makers can modify the properties of aluminum stearate greases by control over (a) viscosity and type of oil, (b) rate of cooling, (c) time of compounding and moisture content, and (d) use of fluxes. With fluxes it is often advisable to use ready-made bases that are designed to give definite desirable results.

**Viscosity Classification of Transmission Oils.** *Automotive Industries* **78** (1938) p. 522.

The Lubricants Division of the S.A.E. Standards Committee has prepared a new classification of transmission lubricants. This was approved by the Standards Committee in January, 1938. Heretofore the separation of transmission lubricants into five classes was based on viscosity at 100°F. The committee deemed it advisable to take the viscosity of the lighter grades at lower temperatures; for example, S.A.E. 80 is a winter lubricant, and the viscosity should be taken at 0°F. S.A.E. 90 is the winter grade in widest use, and the committee decided that the viscosity should be taken at 100°F. The number of summer transmission lubricants was reduced to two, S.A.E. 140 and S.A.E. 250. The viscosities of these grades is to be taken at 210°F. rather than 100°F.

**Fundamentals of Extreme-Pressure Lubricants.** W. F. PAUK, *Petroleum Z. 33, No. 23; Motorenbetr.* **10** (1937) pp. 2-5.

True extreme-pressure lubricants are distinct from mere compounded oils and their action rests on the formation of a film of sulfide or Cl-S compound of the metal over its surface. After this film is formed no further corrosion of the metal surface should occur. The three types of extreme-pressure lubricant are: (1) compounded oils with a Cl-S compound in solution (2) compounded oils with sulfur in solution, and (3) mixtures of mineral oil and lead soap. The first type will withstand the highest pressures, but may become corrosive in the presence of water. The second type does not possess the danger of corrosion of type (1). The third type will withstand up to 15 times as much pressure as ordinary lubricants, but there is danger that lead sulfide will separate. Uses of such lubricants in industry are discussed.

**Reciprocal Action between Bearings and Lubricants.** THEODOR RANOW, *Petroleum Z.* **33** (1937) pp. 1-8.

Four lubricating oils and eight bearing metals were studied in a Kammerer-Welter bearing testing machine. Significant relationships were found for the condition of fluid friction but not for conditions of mixed friction. The limit for most of the metal-oil combinations was found to approach a common value.

**The Use of Colored and Decorative Asphalt for Roads and Buildings.** D. C. BROOME, *Jour. Soc. of Chem. Ind.* **57** (1938) pp. 99-106.

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# The Science of Petroleum

**A Comprehensive Treatise of the Principles and Practice of the Production, Refining, Transport, and Distribution of Mineral Oil**

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Preface by WALTER C. TEAGLE

"It is packed with so much fine information from a fundamental and practical standpoint that it should be a part of the library of anyone interested even in the slightest degree in petroleum and its products. It is a masterpiece! — **Dr. Gustav Egloff.** "A veritable encyclopedia on oil, invaluable as a work of reference."—**The Oil and Gas Journal.**

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as old as civilization, but it is only in recent years that any serious effort has been made to depart from the natural drab color of the materials employed. Although the colored asphalt industry is only about 15 years old, it has long passed the experimental stage, and the author's paper is an account of its present state of development. The mixtures discussed are grouped under the headings of mastic, rolled, and rock asphalt; that is, the materials in which the principal decorative effect is obtained by the use of colored aggregates, and paints. The importance of the bitumen and of the pigment employed, is emphasized and reference is made to the measurement of color, both of the bitumen used and of the finished mixture. Typical figures are given showing the physical and other characteristics of materials suitable for roads and floors of various types. As an example of the progress achieved with seemingly difficult problems the discussion of traffic sign or line mixtures is of interest. These mixtures may be applied to almost any type of existing road, the asphalt or tarmacadam being cut out by means of a special burner or with a hammer and chisel. White and yellow mastics are applied, normally to a thickness of about one half inch. The white mastic is invariably titanium oxide, used either as such, or as titanium lithophone. To make the yellow mastic, cadmium sulphide is best, but because of its cost attempts have been made to replace it with other yellow pigments, and some measure of success has been achieved.

**High-Vacuum Fractional Distillation without Gravitational Reflux.** G. VON ELBE AND B. B. SCOTT, *Ind. & Eng. Chem., Anal. Ed.* **10** (1938) pp. 284-6.

The usual method of fractional distillation involving gravitational reflux cannot be applied to the separation of mixtures of substances of low vapor pressure, since, to maintain a reasonably fast reflux ratio, the vapor pressure of the components must, in general, exceed 1 mm. Furthermore, this method is not applicable to liquid volumes smaller than a few milliliters, since the holdup losses then become a significant fraction of the total input. In the apparatus described the mixture to be fractionated is placed in a rather long, evacuated glass tube, along which for a certain distance a temperature gradient is maintained by means of a thermostatic system. The mixture tends to accumulate at the low-temperature end. By pulling the tube slowly and uniformly through the region of temperature gradient the mixture can be made to distill continuously, and can be separated into its components. The operation of the apparatus is described in application to separation of p- and m-xylenes.

**Laboratory Extraction Apparatus and Its Use in Separating a Lubricating-Oil Fraction with Acetic Acid.** S. T. SCHICKTANZ, *Bur. Stand. J. Res., Wash.*, **20** (1938) pp. 83-6.

A glass laboratory extracting column is described that operates with reflux. It is designed for the use of solvents heavier than the liquid to be extracted. Results are given for the extraction of a narrow-boiling fraction of "water white" lubricating oil with acetic acid.

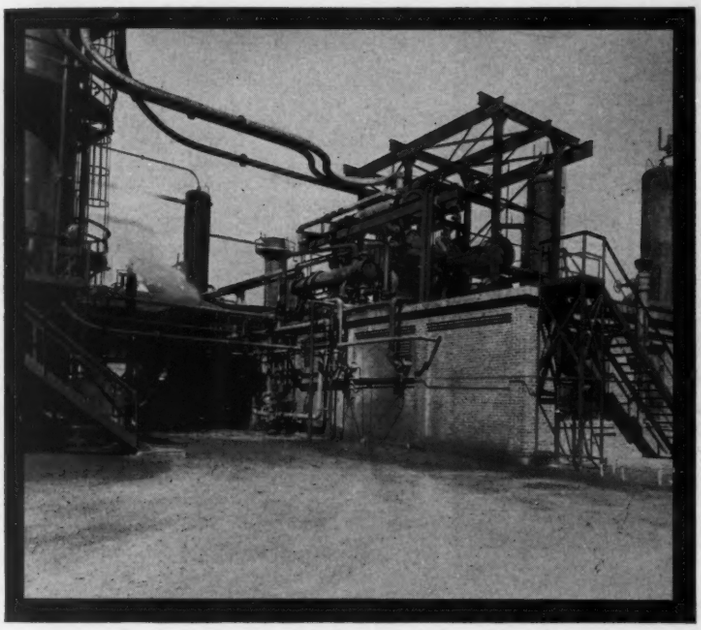
**Determination of Carbon and Hydrogen.** S. NATELSON AND E. B. CONNER, *Ind. & Eng. Chem., Anal. Ed.* **10** (1938) pp. 276-9.

A compact, easily built combustion train for the determination of carbon and hydrogen in samples of organic compounds is described. The apparatus is mounted on one short ring stand, takes up little desk space, and can be easily moved to a convenient place without dismantling, when not in use. The amount of gas used is measured by the introduction of a new type of gasometer, which results in more consistent determinations. Heating is done electrically. Pyrex glass can be used permanently for the combustion tube, when special care is taken and the temperature is kept at about 550°C. It is recommended, however, that, when available, harder glass be used, and a temperature of 650°C. be used for more rapid combustion. The apparatus is described in some detail.

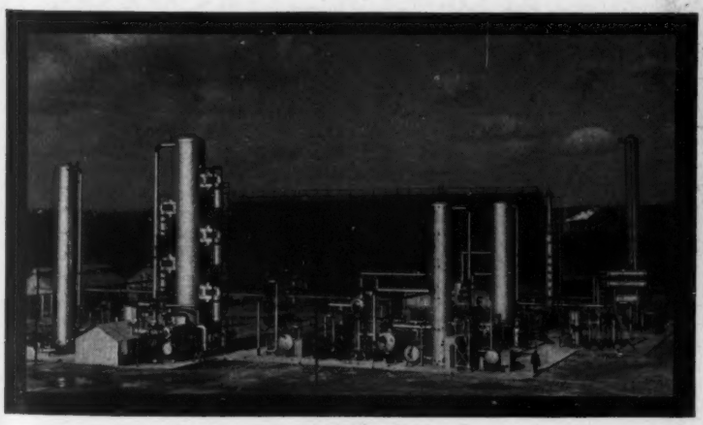
NEW officers of Greene, Tweed & Company, were elected at recent directors' meeting. F. J. Demarest is the newly elected president, with H. G. Russell as treasurer and general manager. J. A. McKeon remains as vice president and H. A. Erwood as secretary.

# TUBES FOR THE OIL REFINER

Condenser and heat exchanger tubes in the oil refining industry form part of a continuous production unit, operating under severely corrosive conditions. In a cracking unit like the one illustrated, which uses nine condensers and heat exchangers, tube alloys must be carefully selected for long life and low maintenance. Bridgeport Brass Company's long experience in tube application is an important aid in alloy selection.



Condensers, coolers, and heat exchangers at this East Texas natural gasoline plant were completely retubed with Bridgeport tubes. In making tube applications, Bridgeport engineers gladly survey specific operating conditions and recommend the most suitable alloy.




Bridgeport

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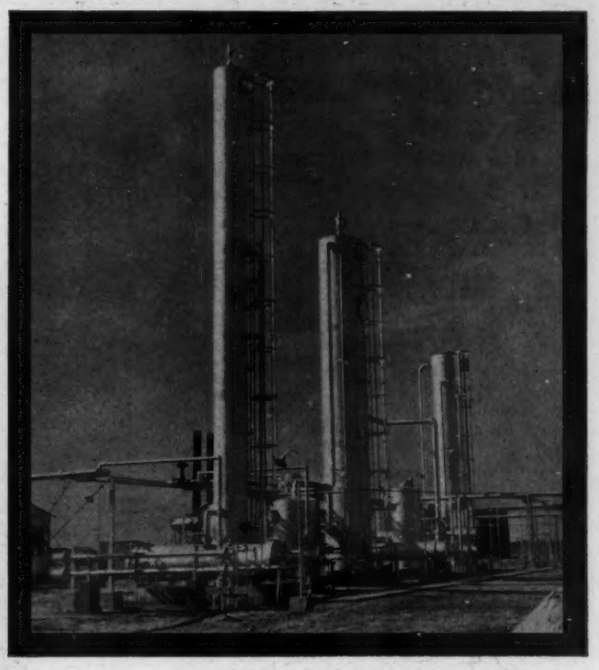

Distillation and fractionation units are subjected to the action of acids, chlorides, and sulphides. For this service certain of the non-ferrous alloys have been found to give excellent results under proper analysis of conditions. Use of a particular alloy depends on temperature, corrosive agents, and other variable factors.

For general industrial piping service Bridgeport Copper Water Tube provides an economical, corrosion-resisting system, easily installed with solder type fittings. To facilitate shipment on rush orders, Bridgeport maintains, in conveniently located warehouses, ample stocks of condenser tubes in the more common alloys, of brass and copper pipe, and of copper water tube.

If you are planning a new or retubing job on condensers or heat exchangers, call in the Bridgeport Condenser man in your territory. His recommendation of an alloy will be based on a survey of your specific needs.

Photos by courtesy of Refinery Engineering & Equipment Co.

# New Equipment for the Modern Plant

## Union Line Blinds

**HAMER OIL TOOL COMPANY**

The Hamer Oil Tool Company of Long Beach, California and Hamer Oil Tool Company of Texas, P. O. Box 2440, Houston, Texas, announce the development and introduction of the new Hamer Union Line Blind, which completely eliminates the old method of blinding lines in refinery, natural gasoline plants, and marine terminal work.

Through the use of the Union Line Blind important savings are made in blinding a line and once blinded by the new device a positive shut-off is accomplished. In the old method of line blinding two men will often spend about one hour removing the bolts, spreading the flanges, reversing the plate and after replacing the gaskets, tighten the bolts to shut off possible leakage. This method involves loss of fluids drained from lines, creates dangerous fire hazards and is expensive.

With the new type of blind it is possible for one man to make the change from open to closed position, securing a positive shut off in less than a minute. The Union Line Blind is now being used successfully on butane, gasoline, pressure distillate, fuel oil and other refinery and gasoline plant fluids. The blinds are made of all-steel parts designed so that castings are as thin as possible and yet maintain great strength. They are recommended for use on working pressures from 1200 pounds down to zero, or made to be placed in vacuum lines. They are available with both ends flanged, threaded or scarfed for welding. They will perform satisfactorily indefinitely and at no maintenance cost.

***Hamer Union Line Blind***

## Air Cleaner

**THE LINCOLN ELECTRIC COMPANY**

The Lincoln Electric Company, Cleveland, Ohio, announces a new machine, which conditions air by filtering out dirt particles and which is said to remove approximately 95 percent of the dirt from the air in the vicinity of grinding, welding and other shop operations.

The machine also draws smoke and heat away from the work thus contributing materially to the efficiency of welders and to the general improvement of shop conditions. It can also be adapted for blowing smoke away where such operation is desired.

The new air conditioning machine, known as the "Linconditioner," has been developed to provide work shops a more economical solution to the problem of cleaning shop air than that obtained with the conventional shop ventilating system. It removes the smoke and dirt at their source rather than after they have combined with large quantities of air. This requires less power. Also, since no air is taken in or blown to the outside of the building, the new machine conserves plant heat.

The "Linconditioner" consists of a motor driven fan which produces suction through a flexible metal tube. The fan draws the air through the flexible

APPROVED

By the U. S. BUREAU of MINES
ACME Full Vision GAS MASKS

Acme FULL VISION Gas Masks Nos. 4 and 4A, with Acme Type 1-OV (Organic Vapors) Canisters, now carry United States Bureau of Mines Approval Numbers 1418 and 1418A.

**Full Vision** is an original and exclusive Acme feature, enabling the wearer to see exactly the same as when not wearing a mask—a most important contribution to safety. Moreover, the Acme FULL VISION Face Piece is the lightest weight Government Approved Face Piece, and the complete masks are the lightest which have yet received the Bureau of Mines Approval.

Other **Acme Features** include replaceable Safety Glass Lenses, scientifically designed Head Harness which eliminates all pressure points on the wearer's forehead, and Dead Air Check Valves to prevent exhaled breath from accumulating in Fresh Air Ducts.

Acme FULL VISION Masks are the utmost in Safety, Comfort and Value. Write for Complete Information and Bulletins on Acme Full Vision Gas Masks or Full Vision Supplied-Air Respirators (Hose Masks).

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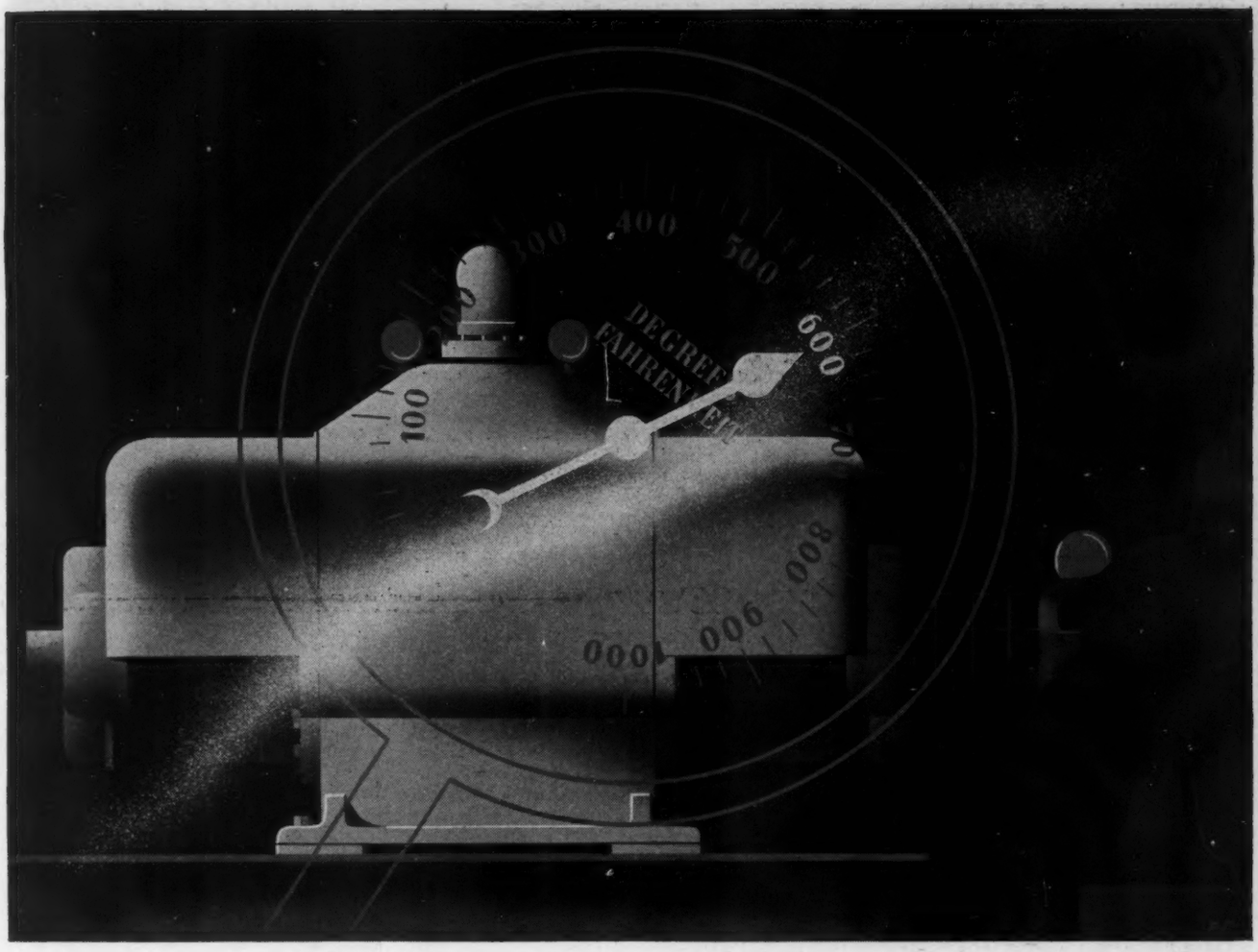


# BETTER MATERIALS FOR HIGHER TEMPERATURES

NEW developments bring new problems. The designing of an improved direct-drive steam engine, for oil-field service, necessitated the use of a material that would withstand continuous subjection to high steam temperature (550° to 600°F.).

The manufacturer adopted a Chrome-Nickel-Moly (0.50–1.00% Mo) iron for vital engine parts. Due to its Moly and Chromium contents, its high growth resistance assures maintenance of the close tolerances necessary to efficient engine performance.

This iron also has advantages from the standpoint of production costs. The castings are free from defects. They have fine grain in the heavy sections and satisfactory machinability in the light sections.

On the foregoing points alone, Moly irons warrant careful consideration. And there are many others, likewise attested in practice. Our book, ***"Molybdenum in Cast Iron,"*** will show the way to more economical high-strength castings. It is free. Climax Molybdenum Co., 500 Fifth Ave., New York.

PRODUCERS OF FERRO-MOLYBDENUM, CALCIUM MOLYBDATE AND MOLYBDENUM TRIOXIDE

**Climax Mo-lyb-den-um Company**

**MOLY**

*"Linconditioner" Air Conditioning Machine.*

tube and exhausts it in a filter which is located in the periphery of the power unit. The flexible tube is supported by a welded steel arm and spring arrangement as shown in the illustrations, so that the nozzle can be shifted to any desired spot within the operating radius of the tubing.

The fan is powered by a one-half horsepower 2 or 3 phase, 60 cycle motor. Motors can be furnished for 110/220/440 volts. Motors ordered for 220 or 440 volts, 60 cycle, can be reconnected from one voltage to another, and can be used on a 50 cycle supply of the same voltage.

## Torque Indicating Wrench

**BONNEY FORGE & TOOL WORKS**

Bonney Forge & Tool Works, Allentown, Pennsylvania, announces a new Torque Indicating Wrench for the proper installation of pipe flanges, couplings, cylinder heads on multi-cylinder gasoline and Diesel motors, pump and turbine casings, etc., where it is required that all bolts be drawn up evenly in order to avoid the possibility of leaks. The new wrench for this purpose is known as the No. 66 Bonney Torque-Indicating Wrench. Features claimed for it by the manufacturer are that it includes ratchet mechanism that is reversible, lack of dials or gauges to get out of order or that may be damaged by careless handling. The handle does not swing free when the desired torque is reached because the ratchet mechanism locks, thus preventing smashed fingers for the user.

*Bonney Torque Indicating Wrench.*

The manufacturer claims that the accuracy of the wrench is greater than the consistent performance of the bolts on which the wrench is used. Its small head permits use in normally inaccessible places. It is not necessary to watch a dial or indicator to see when the desired torque has been reached, and there is no chance or error in reading a dial or gauge.

Simplicity of operation is one of the features of the wrench. The indicator is set at the desired torque in foot pounds. This is done by simply loosening an indicator clamping screw, moving the indicator to the desired position on the scale and then tightening the screw firmly. The ratchet lever is moved to the extreme left of the wrench.

The wrench is operated just as any ratchet wrench until the ratchet lever snaps to the neutral position in center. A sharp "click" is heard and the ratchet locks as a further indication that the desired torque has been reached.

To tighten the next bolt or nut it is not necessary to reset the wrench. The ratchet lever is simply moved back to position at the left of the wrench and the operation is repeated as on the previous nut or bolt tightened. Only when a change in torque is desired is it necessary to move the indicator.

## Welding Electrodes

**GENERAL ELECTRIC COMPANY**

General Electric Company, Industrial Department, Schenectady, New York, announces three new arc welding electrodes, each protected by a heavy extruded coating. These electrodes, designated as Type W-20E, Type W-22E, and Type W-23E, respectively, are intended for shielded arc welding of mild steel.

Type W-20E welding electrode is especially designed for general-purpose, single- or multiple-pass arc welding of mild steel in any position to produce shielded-arc quality in excess of that required to meet paragraph U-69 of the A.S.M.E. Boiler Code. It is particularly suitable for high-speed, single-pass welding and for jobs

Retains butane

Saves raw material for polymerization units

Reduces depreciation and maintenance charges

Reduces fire hazard

Eliminates need for compressors

# CRUDE STABILIZATION

Reduces vapor losses

Eliminates necessity for expensive storage facilities

Removes hydrogen sulphide

Reduces load on recovery units

Increases life of refinery equipment

Retains valuable gasoline hydrocarbons

Crude Stabilization Units can be applied directly in the field, or by a simple modification of existing topping equipment, at the refinery.

Alco designs for a variety of conditions are based on the paramount principle—Economic Justification.

THE PROFITS NOW LOST WILL PAY THE COST.

# ALCO PRODUCTS

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**AMERICAN LOCOMOTIVE SALES CORP.**
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where fit-up is likely to be poor. Spatter loss is low; the weld bead is smooth, and slag is easily removed. The flux coating is hard and not readily chipped, or damaged by moisture. Ductility of the deposit is unusually good and resistance to corrosion is comparable to that of mild steel.

The electrode is recommended for operation with alternating current or direct current (straight polarity).

Type W-22E electrode is designed for high quality, single- or multiple-pass arc welding of steel in any position to produce shielded-arc quality in excess of that required to meet Paragraphs U-68 and U-69 of the A.S.M.E. Boiler Code. Ductility of the deposit is unusually good, and resistance to corrosion is better than that of mild steel. This is a fast-melting, smooth-flowing electrode and with it dense deposits can be made without slag inclusions or gas pockets. Spatter loss is low; slag is easy to remove, and the weld bead is smooth. The coating is hard and not readily chipped or damaged by moisture.

Although vertical and overhead welding with this electrode is usually done with the 5/32-inch size or smaller, the 3/16-inch size can be furnished with two types of coatings, one for overhead and vertical work and the other for horizontal welding. This electrode is recommended for use with direct current (reverse polarity).

Type W-23E electrode is designed primarily for high-quality arc welding of mild steel in the flat position to produce shielded-arc quality in excess of that required to meet Paragraphs U-68 and U-69 of the A.S.M.E. Boiler Code. Ductility is excellent and resistance to corrosion is better than that of mild steel.

This is a high-current, or "hot" rod, so that the weld metal is quite fluid and washes up well on the side walls of deep-groove joints and fillets. Single- or multiple-pass beads can be made at high speeds without slag inclusions or gas pockets. Spatter loss is low and slag is easy to remove. This electrode also has a hard flux coating which is not readily chipped or damaged by moisture. A modification of this electrode, is also available in coils with heavy taped coating for automatic welding. This type of electrode is recommended for operation with alternating current or direct current (reverse polarity).

THE Sharples petroleum research men can look back on over twenty years world-wide contact with oil refining and centrifugals. Their laboratory is physically entirely separated from Sharples non-petroleum research. Many of the world's leading oil technologists have been their guests. By these contacts and by years of earnest search and study they have well earned their unique position in the application of centrifugal force to that field. Be it dewaxing or acid treating of lubricating stocks or pressure distillate or white oils, or any of numerous other uses of centrifugal force, these experienced men and their equipment are available to the oil industry.

☆

**The Sharples Specialty Company**
**2335 WESTMORELAND STREET**
**PHILADELPHIA, PA.**

## Gas Masks

**MINE SAFETY APPLIANCES COMPANY**

Mine Safety Appliances Company, Pittsburgh, announces improvements in its industrial gas masks, with broad selection of cannisters for protection against practically all poisonous industrial gases. Features of the M.S.A. industrial gas mask are its light weight, wearing comfort and design that permit complete freedom of action. Through its use the wearer is protected and not hampered in the normal performance of his duties, it is claimed.

## Pipe Vise Stand

**THE OSTER MANUFACTURING COMPANY**

The Oster Manufacturing Company, Cleveland, Ohio, has just announced a new pipe vise stand of the usual type, but equipped with a power unit and chuck which enable the user to thread, cut and ream all sizes of pipe up to 2-inch inclusive, by power.

The pipe is gripped in a universal, bar-operated, scroll type chuck and is revolved by the power unit concealed in the upper part of the stand on which the pipe vise is usually mounted.

The die-stock, cutter or reamer is placed on the pipe in the conventional manner with the handles resting on sliding arms which are built in the sides of the stand. When the power is turned

*Oster Power Vise Stand*

on, the sliding arms take the torque of the pipe tools as the threading, cutting-off and reaming operations are performed.

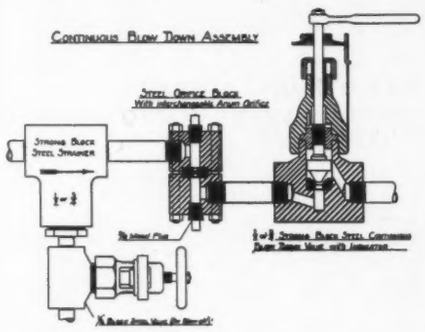
In appearance and construction, the new power vise stand is similar to the usual type. The power is furnished by a universal, variable speed motor, geared to the spindle holding the chuck, giving the chuck variable speeds from 14 to 32 r.p.m. according to the load of the cut. The motor can be connected to the ordinary 110 volt lighting circuit.

The legs of the stand are regular pipe of 1-inch diameter, giving it a height of 40 inches. The width is 20 inches and the length overall including carrying handles is 30 inches.

## Continuous Blowdown Assembly

### THE STRONG, CARLISLE & HAMMOND COMPANY

The Strong, Carlisle & Hammond Company, Cleveland, Ohio, has developed a new type of continuous blowdown assembly for boilers, designed to attack the problems of accurate metering and valve maintenance. The system is based on an initial pressure drop ahead of a special, steel blowdown valve. Pressure is reduced by a fixed Anum-metal orifice that determines the maximum flow. This results in a proportionate increase in volume due to reflash. Accuracy of control through the blowdown valve therefore, is multiplied in the same ratio that the volume has been




increased. Regulation is made still more exact by the special restricted seat and the position indicator of the blowdown valve. At the same time, the reduced pressure subjects the valve to less severe service, greatly prolongs its life and reduces maintenance. Standard valves are furnished for pressures to 650 pounds or temperature to 800 degrees.

## Steam-Jet Ejectors

### WORTHINGTON PUMP AND MACHINERY CORPORATION

Worthington Pump and Machinery Corporation, Harrison, N. J., announces an improved line of two-stage, condensing type, single and double element steam-jet ejectors.

These two-stage ejectors have surface type inter and after condensers, and are generally used in connection with surface condensers serving turbines in steam power plants. They can also be used in industrial processes where valuable volatile constituents entrained in the gases being compressed can be recovered by condensing them in the inter and after condensers. These


WATSON- **W-S** STILLMAN

**FORGED STEEL FITTINGS**

**On pipe lines carrying oil or gas at high pressures and temperatures, use W-S Forged Steel Fittings.**

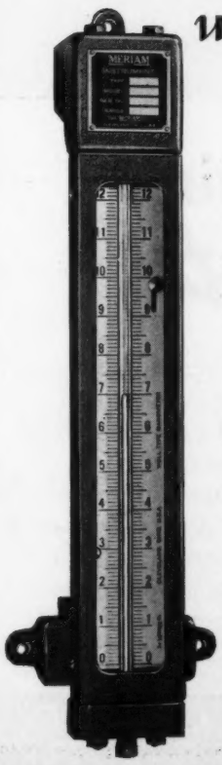
**Especially designed for oil and gas service, these easily applied, rugged fittings can be relied on for longer and more dependable service.**

**For complete satisfaction and lower costs in pipe line maintenance, specify W-S Forged Steel Fittings.**

***Write for information on the line of sizes and types available, or get in touch with your nearest supply house.***

**THE WATSON-STILLMAN CO.**
**ROSELLE, NEW JERSEY**

*SAVES* **Costly Mercury Loss** *when Meter "Blows Over"*



**MERIAM CLEAN-OUT WELL TYPE MANOMETER**

Model CO is designed to save time, trouble and expense when excessive pressure causes blowing of the mercury. The upper gauge well serves as a trap preventing loss of the mercury. The fluid then automatically returns through the glass tube to the lower well.

For use on moderate operating pressures, Model CO Manometers range in size from 12" to 100". Moisture traps are available for use in measuring pressures of saturated gases or vacuum pressures of steam condensers.

Accuracy, easy maintenance and quality construction are three excellent reasons for the widespread use of Model CO. Write for Bulletin No. 19.

**THE MERIAM CO.**
CLEVELAND, OHIO • Representatives and Jobbers in Principal Cities

two stage ejectors can also be provided with barometric jet type inter and after condensers for use in connection with industrial processes.

The single element ejector is used primarily on small units where temporary shut-downs are permissible and where reserve ejector capacity is not essential.

Each element of the twin unit is capable of handling normal capacity, and the unit is provided with suitable isolating valves to permit operation of either one or both elements. The spare element can be used for standby service or to take care of abnormal air leakage to the extent of doubling capacity.

Among other improved details, the manufacturer states that these new units are equipped with removable monel steam strainers integral with the nozzle heads, to eliminate clogging of the nozzles and facilitate minor adjustments. Parts subject to high pressure have been fabricated of improved materials, and safety valves are provided on the first stages of twin units to provide protection against closing of the interstage isolating valves at the wrong time. Overall dimensions have been reduced and designs for all sizes standardized. The performance of these improved units is approximately 20 percent better than that of equipment heretofore furnished.

New, Money-Saving
Screen Cloth

RECENTLY developed after extensive research, this Mud Screen Cloth is metallic hook bound, rubber cushioned. It is particularly designed for use on standard type shakers for reclaiming and conditioning rotary drilling mud.

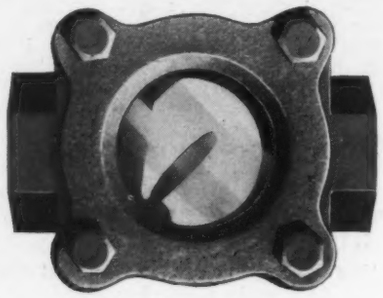
Cambridge manufactures Wire Screens for use in all type screens. They are uniformly high in quality due to systematic and accurate control of every step of manufacture, in our own plant. They cost less, hundreds in use have proved they save you money in production. For information, consult the Cambridge engineer in your territory or write us.

CAMBRIDGE WIRE CLOTH CO.
CAMBRIDGE, MARYLAND
Boston - New York - Baltimore - Pittsburgh - Detroit - Chicago - San Francisco - New Orleans


## Sight Flow Indicator

**FISCHER & PROCTOR COMPANY**

Fischer & Proctor Company, 110 West Penn Street, Germantown, Philadelphia, Pennsylvania, announce the development of the F & P Bull's Eye Sight flow indicator, which is used for determining whether fluid is flowing through a pipe. It does not meter rate of flow, it simply indicates flow, if any.



***Sight Flow Indicator***

The indicator consists of a simple pipe fitting with two round sight glasses located on opposite sides and held in position by easily removed bolted cover plates. Neoprene or thiokol packing is used. Between the glasses is a flapper suspended in such a manner that it hangs against a seat when there is no flow. As soon as flow commences the flapper swings outward and upward to be easily visable to the operator checking flow through the line.

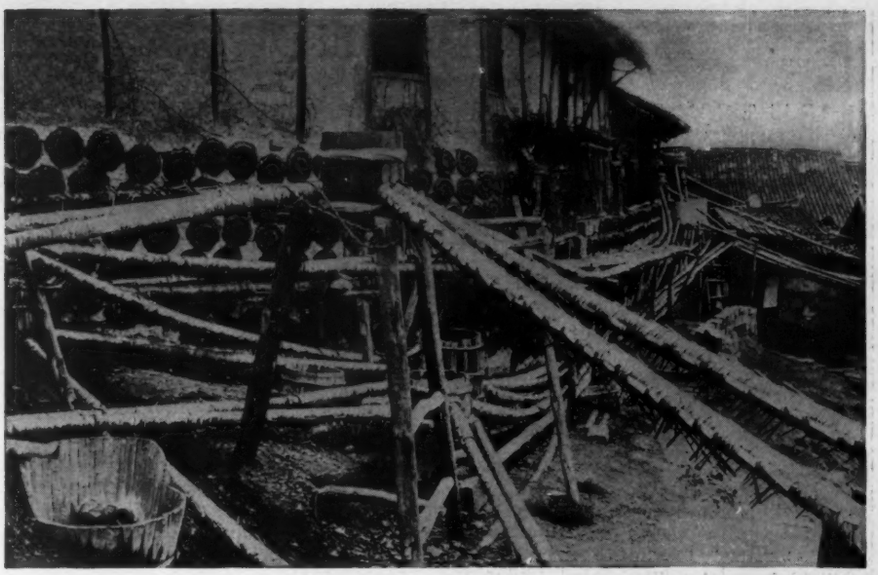
## Centrifugal Pump

**ALLIS-CHALMERS MANUFACTURING COMPANY**

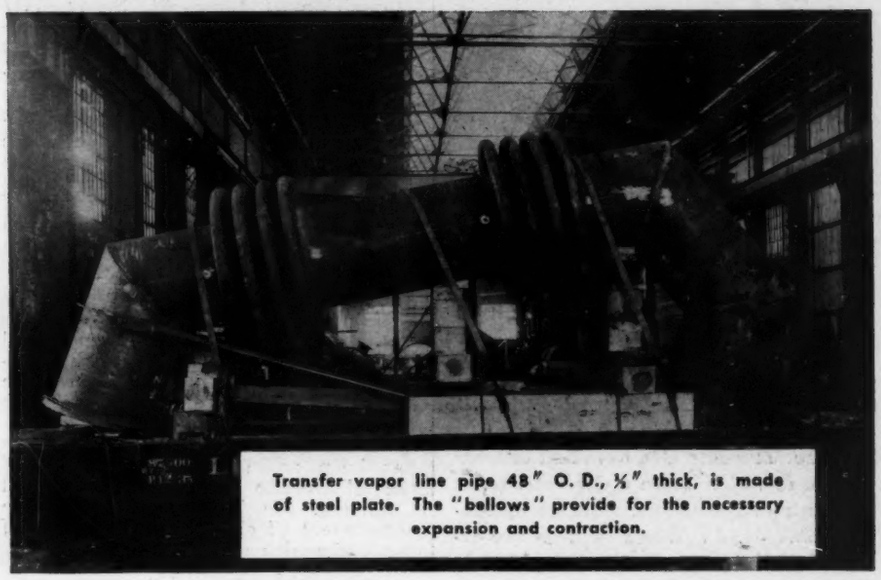
Allis-Chalmers Manufacturing Company, Centrifugal Pump Division, Milwaukee, Wisconsin, has supplemented its line of single-stage "SSUnit" type pumps by adding a 2½ x 1½-inch two-stage "SSUnit" type pump good for heads up to 525 feet at 3550 revolutions. This pump has an efficient capacity range of from 50 to 100 g.p.m. against heads of from 300 to 500 feet. It is bolted to the motor frame by a splash-proof connection piece, the impellers being mounted on the special motor shaft extension, and the motor bearings also being the pump bearings like in their usual "SSUnit" construction.

This pump is available with motors of from 10 to 30 horsepower of the standard squirrel-cage type, splash-proof or explosion-proof types, and is an adaptable pump for small boiler-feed pumps—humidifier pumps in textile mills—air conditioning service—house pumps—small mine pumps—oil gathering, loading and small pipe line pumps and other small capacity, high-pressure services.

It operates with unusual smoothness and the efficiency holds up well over a wide range. The standard pump has cast-iron casing and cover, and is bronze fitted. The impellers are placed back to back providing axial balance with the suction impeller next to the motor and the discharge passage from the first stage impeller cast integral with the main casing body and communicating with a passage in the cover leading to the inlet of the second stage impeller.



# PIPING OF GRASS



Transfer vapor line pipe 48" O. D., ½" thick, is made of steel plate. The "bellows" provide for the necessary expansion and contraction.

# PIPING of STEEL

Piping made of bamboo (a species of grass) has been used in Chinese oil refineries for over 1,000 years. In many of the older plants it is still used today.

Modern methods of refining necessitate the use of piping fabricated from special steels, able to withstand high pressures and temperatures, and extreme thermal variations.

The transfer vapor line pipe illustrated above is a recent example of special piping for refinery service fabricated in the Kellogg shops.

Whether you require piping for a single unit or an entire piping system a Kellogg engineer will gladly assist you.

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*Portrait of a*
**"MODERN"**

**IF this 6-inch elbow had been a flanged fitting assembly, it would have tipped the scale at 242 pounds instead of 27 pounds. Moreover it would have contained 53 pieces instead of just one Taylor Forge Seamless WeldELL.**

**If it had been a screwed fitting it would have been bulky and difficult to insulate. It would also have had interior shoulders which cause a flow resistance many times greater than the smooth-interior WeldELL. Worse still, on the order of 32% of the pipe wall would have been cut away by threading.**

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**The Taylor Forge line of seamless steel welding fittings contains the widest range of types, sizes and thicknesses. Large stocks are carried by distributors serving every branch of the oil industry Ask for WeldELLS.**

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# ▼ BUSINESS NOTES ▼

BIGGS & COMPANY, Wichita Falls, Texas, has been appointed distributors of the complete line of N.Y.B. & P. Mechanical Rubber Goods in the Wichita Falls district, it has been announced by B. F. Ruether, general manager, New York Belting & Packing Company.

RAYMOND M. DENNIS, who has been superintendent of flanging at Lukens Steel Company, Coatesville, Pennsylvania, has been appointed general manager of the flanging department in charge of estimating, sales and production on flanging work.

ALLEGHENY STEEL COMPANY and Ludlum Steel Company announce that effective immediately the Pacific Coast business of both companies will be consolidated under the supervision of James H. Spade, 1417 Santa Fe Avenue, Los Angeles. Complete warehouse stocks of the products of both companies will be established.

THE TIMKEN ROLLER BEARING COMPANY announces the appointment of David T. Marvel as manager of tube sales. He will have full charge of the sale of all forms of Timken seamless steel tubing. His headquarters will be at the main office in Canton, Ohio.

HOWARD V. SMITH, of El Dorado, Kansas, has been appointed chief chemical engineer of Barber Asphalt Corporation in charge of the company's technical department, James E. Auten, president, recently announced. For the last 11 years Smith has been assistant superintendent of the El Dorado refinery of Skelly Oil Company. He is a graduate of the department of chemical engineering of the University of Kansas.

J. Strother Miller, Jr., formerly director of the technical department of Barber Asphalt Corporation, has been advanced to be technical adviser to the company.

W. K. MELLON, vice president in charge of sales and service in all territories, Petroleum Rectifying Company, recently returned from a business trip to the Gulf Coast and left shortly thereafter for a more extended trip through the eastern and Great Lakes sections. He was scheduled to meet Gordon B. Hanson, district manager, and L. C. Waterman, district engineer, both of the Houston office, in Chicago; from which point his itinerary eastward includes Pittsburgh, Philadelphia, New York City, and Cleveland. On the return trip, Mellon may also visit Buffalo and Montreal, returning to headquarters via the southern route and stopping for a short visit at the Houston branch.

A. J. WADHAMS, vice president and manager of Development and Research Division, of The International Nickel Company, Inc., has announced the establishment of a new field office located in the Grant Building, Pittsburgh.

The office is under the direction of H. V. Beasley, who for the past three years has been attached to the New York office.

The main function of this office will be to promote applications of Nickel alloy steels and products of the Huntington Mill and stimulate interest in Nickel cast irons and the use of Nickel in non-ferrous alloys.

This is the fifth field office opened by the Division to give manufacturers in the various industrial districts prompt service in handling their metallurgical problems. Other offices are located in Los Angeles, Chicago, Detroit, and Hartford, Connecticut.

STRUTHERS-WELLS Titusville Corporation has announced appointment of Hyman Ledeen, 747 Warehouse Street, Los Angeles, as sales representative in the lower part of California, Arizona and New Mexico, and the western part of Texas.

MURPHY DIESEL COMPANY, Milwaukee, Wisconsin, announces appointment of William Mehler as Western district manager.

Mehler has long experience in the Diesel field, and was at one time connected with one of the major fire apparatus builders, who also build Diesels. He served this company for seven years in the capacity of field sales engineer. He left this company to go into the employ of a large motor prod-

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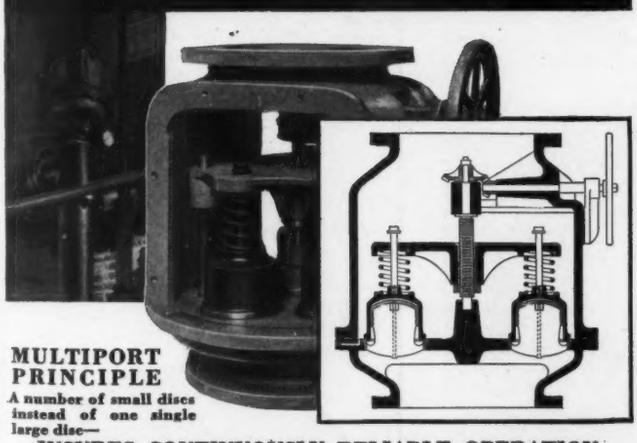

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ucts company in the capacity of district sales engineer. He has behind him 20 years experience in the gasoline and Diesel engine fields, covering both building and sales engineering. He will be located at 255-10th Street, San Francisco.

**TOM W. NELSON**
***Heads Gulf Publishing Company Catalog Department***

EFFECTIVE June 15, Tom W. Nelson, for several years manager of the Chicago office of the Gulf Publishing Company, was made manager of the Composite Catalog Department of the company with headquarters at Houston.

Nelson has been with the company since 1927, having served in both the

**H. G. FITZPATRICK**
***Representing Gulf Publishing Company at Chicago***


# KINNEY PUMPS

## Wherever oil is refined or shipped you will find Kinney Pumps

and for the same reasons—reliability, efficiency, and low upkeep cost during many years of service.

From Halifax, Nova Scotia to Puget Sound; from Chicago to Galveston—in Mexico, Venezuela, Brazil, Peru and the Argentine — you will find Kinney Pumps loading ships, unloading barges, charging stills, pumping asphalt, and doing a variety of useful pumping jobs.

Shiploading in the Hawaiian Islands — charging stills and handling hot oil in Japan — pumping fuel oil, kerosene, and asphalt in China — barge pumps in the Philippines — asphalt, fuel oil, and other refinery units in the East Indies — tar pumps in India — barge and ship-loading units in the Bahrein Islands, Iraq — asphalt pumps in Italy and Germany, and many many more!

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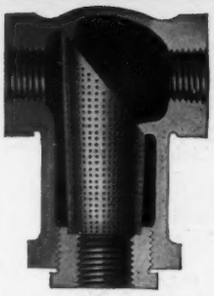
PIPEWRENCH PETE SAYS:

DO I LOOK LIKE TH' GOLD DUST TWINS?



Nights, and Sundays too, I've put in, fixing regulating valves and controls . . . only to find that dirt and scale was causing the trouble.

Thought I'd ask the boss if I looked like the Gold Dust Twins. Instead, I just got some Strong Strainers and put one ahead of every valve and control. Believe me, they do the job. Now, all I've got to do is open a few blow-off valves, and out comes the dirt and scale.

Send for your copy of Bulletin 154

**STRONG**

**STRAINERS**

The Strong, Carlisle & Hammond Company
1392 West Third Street, Cleveland, Ohio

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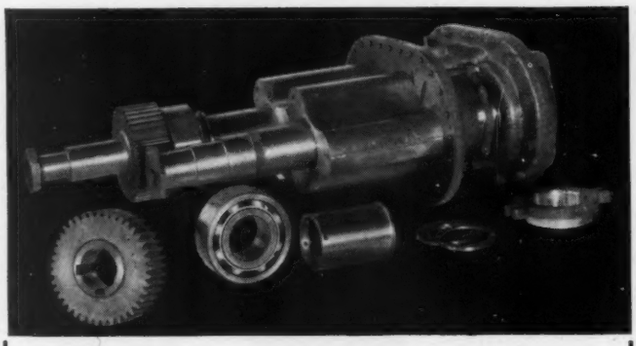

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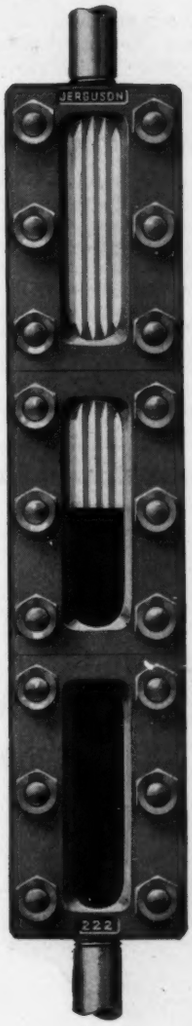


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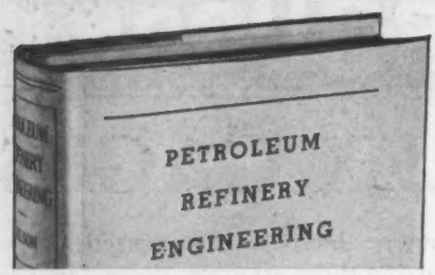


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Pittsburgh and Chicago territories in charge of sales in Ohio, Indiana, Illinois, Missouri, Michigan, Minnesota and Kentucky.

H. G. Fitzpatrick, who has been handling Composite Catalog sales in the East, has been made manager of the Gulf Publishing Company's Chicago office. Fitzpatrick came to the Gulf Publishing Company in 1936, from the Griswold-Eshleman Company, advertising agency of Cleveland, where he was connected with several accounts selling to the oil industry.

ANNOUNCEMENT has just been made of the establishment of a new steel drum manufacturing plant at Port Arthur, Texas, by Wilson & Bennett Manufacturing Company.

This new modern plant, located at Washington & West 11th Street, is expected to be in full operation soon and will be equipped with complete up-to-date production lines for manufacturing all standard sizes of steel drums and barrels.

This is the fourth manufacturing unit of this company—three of which have been equipped and put into operation during the last five years—an unusual record of progress made during a period when business generally has not entered into expansion programs. The other plants are located at Chicago, Jersey City and New Orleans and sales offices and warehouses are maintained in 32 principal cities.

E. B. TREIDLER is now special representative for Air-Maze Corporation, covering Southern California and Arizona. He is representing the complete line of Air-Maze air filters for oil field engine and air compressor applications.

Until a few months ago Treidler was connected with Alpha Steam Specialty Company, New York City, an Air-Maze distributor. There he became impressed with the possibilities of handling the Air-Maze line in California, his "home territory," where he had formerly spent many years working with industrial accounts.

Accordingly, when Harvey L. Laughlin Company of 1315 E. 7th Street, Los Angeles, was recently appointed factory representative for Air-Maze, Treidler joined them to take charge of the Air-Maze account.

THE American Sand-Banum Company, Inc., of 9 Rockefeller Plaza, New York, announces appointment of The Great Southern Company, 822 Perdido Street, New Orleans, as its sales agents in Louisiana.

This company will work directly with Western Sand-Banum Company in Houston, which is the Gulf Coast District headquarters of the parent company. In the promotion of the product Sand-Banum The Great Southern Company will co-operate closely with the leading supply houses in its area who also handle this boiler treatment.

J. J. B. RUTHERFORD, formerly of the research laboratory, United States Steel Corporation, Kearny, N.J., has joined the metallurgical staff of The Babcock & Wilcox Tube Company as research metallurgist.


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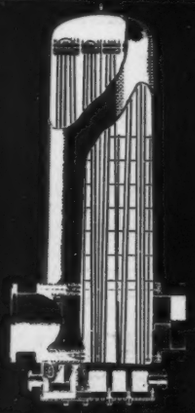

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- Also available in standard models with head diameter 3"

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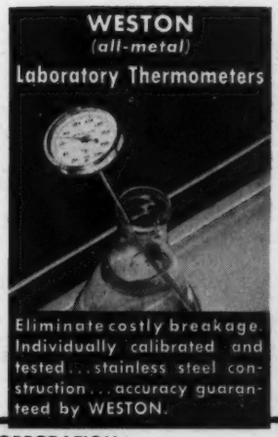


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# CATALOGS . . . BULLETINS

## *Helpful Publications Which Manufacturers Will Be Glad to Send Free for the Asking*

### Pumps

Ingersoll-Rand Company, Cameron Pump Division, 11 Broadway, New York, is distributing Bulletin 7069 describing the new Ingersoll-Rand end-suction centrifugal pump, style CRV, which is built in capacities up to 1000 gallons per minute for heads up to 500 feet. The pumps offer single- or two-stage construction, open or closed impeller and motor, steam turbine, gasoline engine or belt drive. Photographs of several installations and complete tables of performances and dimensions are included.

### Cleaners

Homestead Valve Manufacturing Company, Coraopolis, Pa., is distributing new literature describing two new models, J and K, of the company's Hypressure Jenny, steam vapor spray cleaners used for removing grease, dirt, mud, oil, tar and other deposits from motors, chassis, parts, machinery, floors, walls, etc. The new models have greater accessibility, are more compact, do quicker and more effective cleaning, operate more economically and cost less than previous models, it is said.

### Valves

Homestead Valve Manufacturing Company, Corapolis, Pa., has published the new Homestead Valve Reference Book No. 38. This book features a wide line of lift-plug valves, boiler blow-off valves, and includes more complete dimensions, tables, and facts about Homestead valves. A new line of semi-steel 500-pound oil, water and gas valves for the oil industry is described.

### Level Indicator

The Reliance Gauge Column Company, Cleveland, Ohio, is distributing Bulletin No. 382 describing its new Reliance Eye-Hye remote-reading liquid-level indicator for boilers, which brings the water gauges down to eye-level for safe convenient control. The company has also brought up to date its bulletins on Reliance Boiler Alarms, Liquid-Level Control, Water Gauge Valves, and High-Pressure Water Gauge Equipment.

### Belting

New York Belting & Packing Company, Passaic, N. J., has issued a 32-page belting data book designed to insure the most efficient application of industrial belts to the specific purpose for which they were designed. The book is packed with illustrations and information, including recommendation tables, cover thicknesses, horsepower tables, types of drives, tables of speeds, ply recommendations, tensions, belting layouts and so forth.

### Control

The Bristol Company, Waterbury, Conn., has published bulletin No. 513 describing that company's Metavane system of pneumatic telemetering, giving information regarding the use of this instrument, particularly in hazardous atmospheres, for recording and controlling flow, temperature, pressure and liquid level at a distance from the source of measurement. Bulletin 506 deals with the Metameter system for telemetering and remote control and in this booklet the system is illustrated by photographs and chart records, which give a few of the interesting facts regarding an installation of these instruments for remote, automatic control of gas distribution pressure. In Bulletin No. 488 the company describes a wide line of Millivoltmeter Pyrometers. This line includes indicator controllers with enclosed mercury contacts or solid metal-to-metal contacts, single point indicators and multiple-point indicators with rotary switch.

### V-Belts

The Manhattan Rubber Manufacturing Division, Raybestos-Manhattan, Inc., Passaic, N. J., is distributing a new 4-page Bulletin No. 6868, which describes technical details of the functions and construction of V-Belts of the Condor Whipcord type as produced by this company. Several interesting photographs of installations are shown and price list and a V-belt comparison table are included.

### Line Blind

Hamer Oil Company, 2911 Cherry Ave., Long Beach, California, is distributing literature describing the new Hamer Union Line Blind, a new positive shut-off that works with speed and safety. The bulletin describes the new line blind in detail and by means of drawings and photographs to supplement the text tells the complete story effectively. Included in the catalog are descriptions of other Hamer products such as the E-Z Turn Plug valve, slush pump pistons and slush pump liner sleeves as well as pump valves and seats.

### Equipment

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., has published a new illustrated brochure "Westinghouse Equipment for the Petroleum Industry," which by means of text, drawings and photographs presents information on that company's products for use in the oil industry from drilling rig to service station.

### Fire Fighting

Walter Kidde & Company, 140 Cedar Street, New York, has published a revised bulletin, "Instant Death to Any Fire," containing latest engineering and technical information on Lux carbon dioxide portable fire extinguishing equipment for use against electrical, flammable liquid, and many other fire hazards. The 4-page bulletin completely describes extinguishers from the 2-pound size up to the 100-pound wheeled extinguisher and auxiliary equipment.

### Vacuum Pumps

F. J. Stokes Machine Company, Philadelphia, has issued "Stokes High Vacuum Pumps," which is a hand book on these pumps as well as a catalog. It catalogs five sizes of pumps from 10 to 225 cubic feet capacity and contains pump information of value to anyone working with vacuum in its higher ranges, from around 28 inches up to within a few microns of absolute. The handbook section is filled with data, charts, graphs, tables of interest and the book is a comprehensive presentation of the story of higher vacuums, its applications, advantages and economics in industry.

### Asphalt Blending

%Proportioneers, Inc.%, Providence, Rhode Island, has issued a new treatise on automatic asphalt blending called Standard Methods No. 110. The bulletin illustrates and describes typical Proportioneers continuous automatic cut-back asphalt blending installations, gives installation diagrams of Tret-O-Control equipment and Tret-O-Unit meters. The apparatus is completely described and all pertinent engineering information is included.

### Pumps

Ingersoll-Rand Company, 11 Broadway, New York, is distributing Bulletin 2390 describing a new turbine-driven pump featuring a compact construction that combines both turbine and pump as one unit on a common shaft. The pump is built in single-stage sizes in capacities ranging from 5 to 1000 gallons per minute against heads as high as 220 feet, and in two-stage sizes from capacity to 275 gallons per minute and heads up to 550 feet.

### Diatoms

Johns-Manville, 22 East 40th Street, New York, has recently published a revised edition of the booklet "Research Puts the Diatom to Work." The booklet describes the characteristics and history of the microscopic vegetable known as the diatom and tells of the research which has converted the tiny siliceous valve of the organisms into an industrial item of great economic significance. Written in interesting fashion in the language of the layman, it reveals how hundreds of different types of finished products are developed mainly from raw material.

### Refractories

Johns-Manville, 22 East 40th Street, New York, in Form DS Series 700, a new 20-page engineering data book, has made available full information on the J-M Line of refractory products, including cements, castables and plastics. The descriptive material includes data on the character or base of each product, its highest working temperature, the number of pounds needed to set 1000 brick or form one cubic foot of construction, and the form in which the product is furnished. One of the most valuable features is a comprehensive table which lists separately the various types of heated equipment used in a large number of industries. For each piece of equipment the table describes the parts requiring a refractory cement and recommends a specific product for the job.

### Carbon Cells

Le Carbone Company, Inc., Boonton, New Jersey, has issued new literature on the newly developed Le Carbone air depolarized carbon cells. Bulletin No. 6 devotes one page to descriptions of instrument cells especially designed for use by users of instruments such as recording pyrometers and resistance thermometers. Long life and remarkably even voltage characteristics of these cells are great practical advantages in instrument work, it is said.

### Packing

The Garlock Packing Company, Palmyra, New York, is distributing new literature describing Garlock Bitan leather packings for such service as in hydraulic service against cold water, hot water, oils, gasoline, air, gas, and against slightly acid or alkaline solutions. Garlock Bitan leather packings are made as molded cups, "U" or "V" packings, flange or hat packings, washers, gaskets or discs.

### Electrodes

Harnischfeger Corporation, Milwaukee, Wis., manufacturers of P&H-Hansen Welders, has published Bulletin R-5, which gives complete and specialized information and data on each of the many Smootharc Welding Electrodes. The bulletin includes spar tests, procedure sheets and many other informative suggestions to make it a valuable reference book for all welder users and operators. Its information is applicable where the job is welding Man-Ten steel, chrome steel, stainless steel, manganese steels, nickel steel, etc., and in overhead, downhand or poor fit positions.

### Brick

Harbison-Walker Refractories Company, Pittsburgh, has published a new bulletin "Super Duty Brick for Super Duty Service." The context points out the factors which led to the development of these refractories in which definite properties have been developed to meet service conditions beyond the limits of high-heat duty fire-clay brick. The folder contains information regarding the manufacture, properties and applications of these refractories.

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